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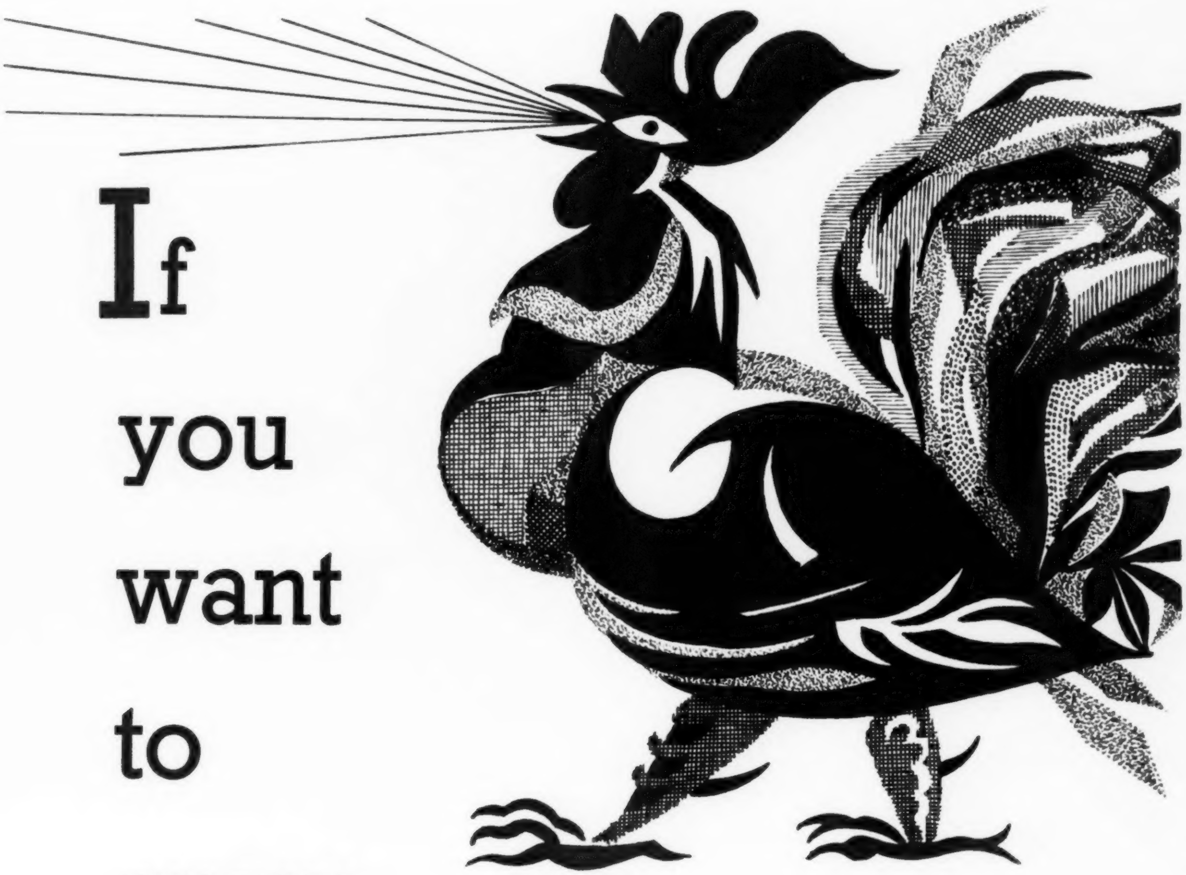


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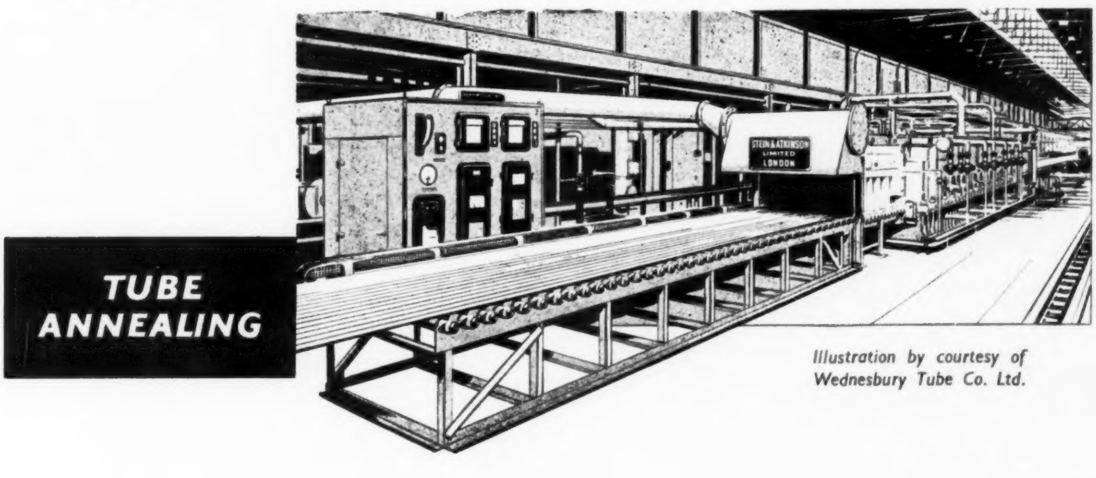

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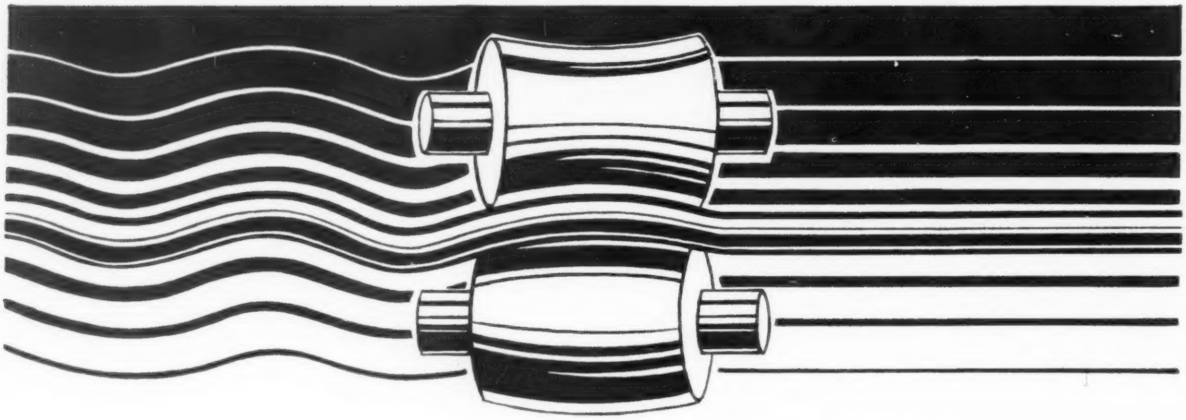

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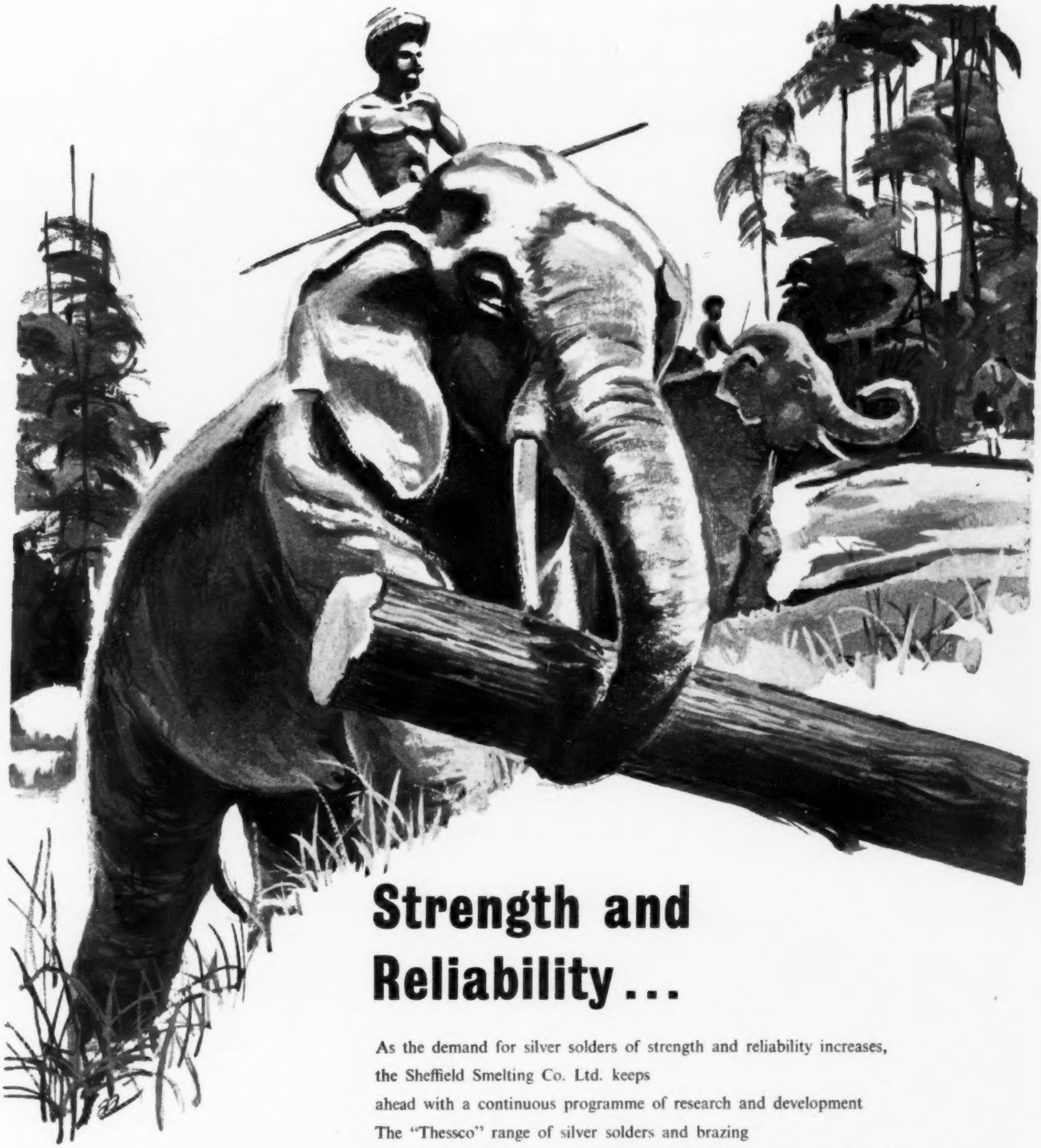

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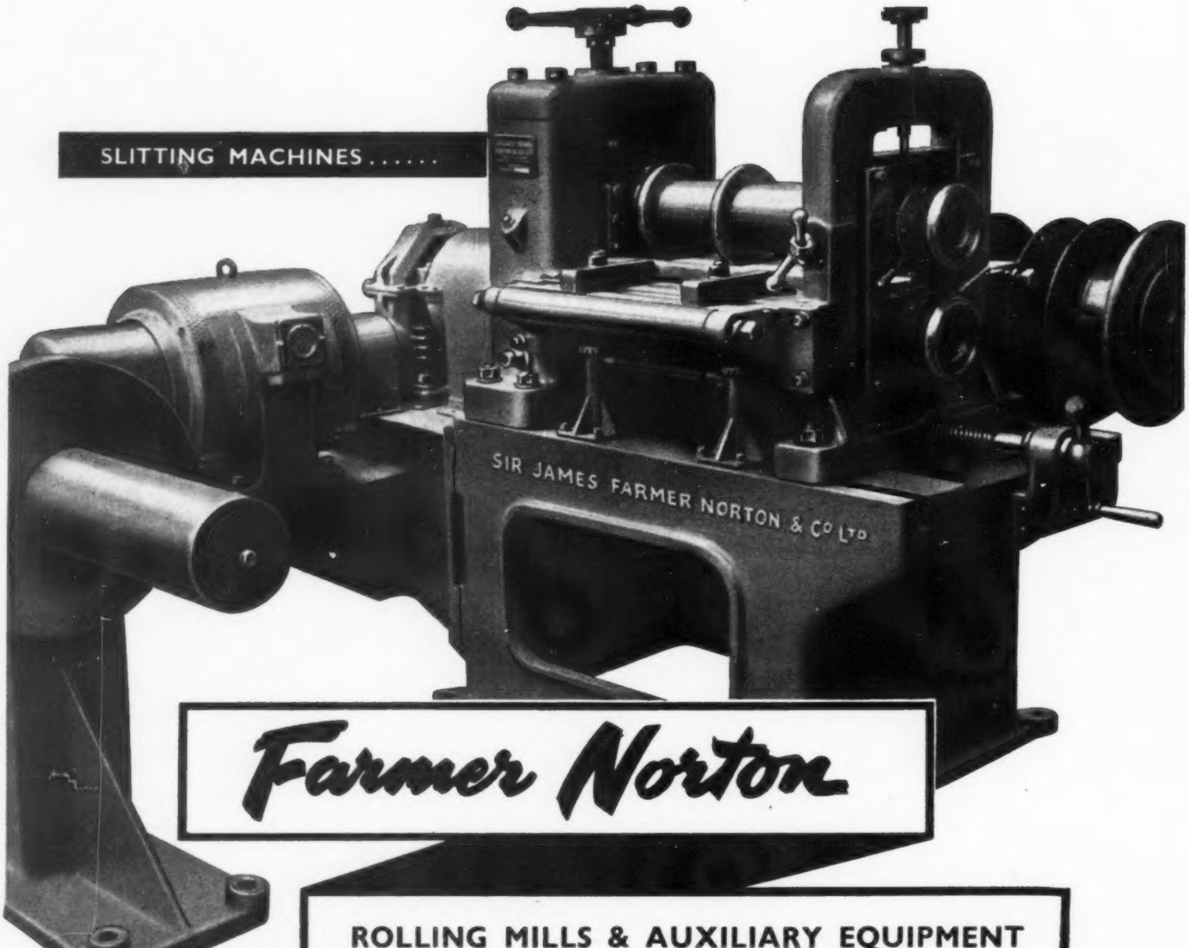

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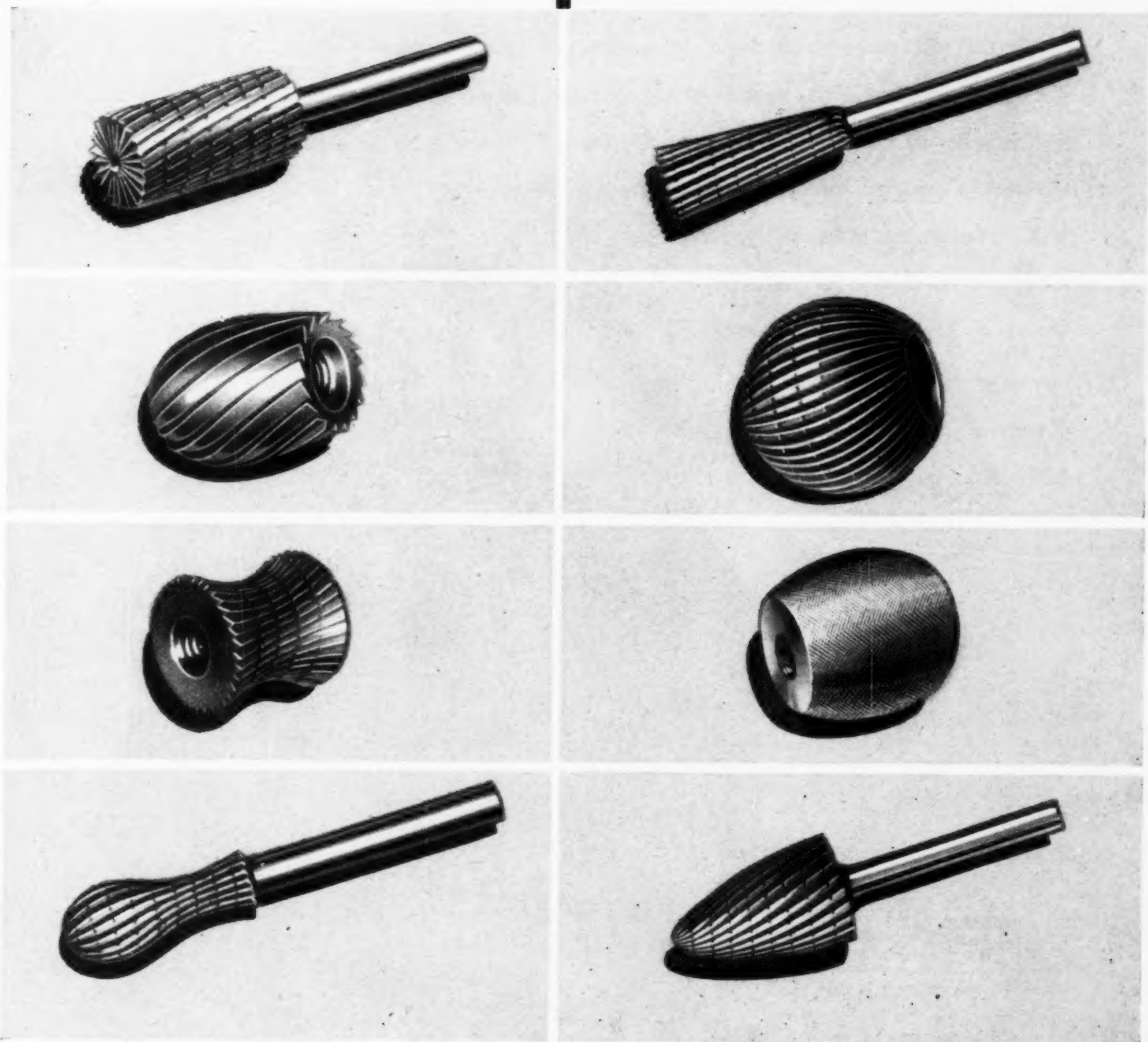

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METAL INDUSTRY

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METAL INDUSTRY

VOLUME 95 NUMBER 3 28 AUGUST 1959

The Radcliffe Report

SINCE the last issue of this journal went to press, the report of the Committee on the Working of the Monetary System, familiarly referred to as the "Radcliffe Report," has been published, and a particular feature of the report is its unanimity. One main point urged by the Committee is that a new committee should be set up, headed by the Chancellor of the Exchequer, to advise on the co-ordination of monetary measures. At the same time, it stresses that monetary measures can "help" to control the economy "but that is all." The report also deprecates "doctrinal preferences" for one form of control rather than another, and stresses the need for more information and analysis.

The report is a document of 360 printed pages, twelve chapters and three appendices, and it contains a great deal of statistical information which has not previously been available. In its first chapter the Committee reviews the background to post-war monetary policy, pointing out five features which distinguish the post-war from the pre-war situation. These are: (1) high employment; (2) the increase in the national income; (3) the persistent rise in prices; (4) the pressure of overseas demand; and (5) the world-wide shortage of capital. It would be impossible for us to deal with such a lengthy document in the small space available here but probably the section of the Report which would be of most interest to our readers, apart from the chapter dealing with banking facilities for industry generally on the purely domestic side, etc., will be Chapter XI, in which there is comment on the financing of exports, small business and industrial innovation, and the transfer of payments.

The role which the Export Credits Guarantee Department of the Board of Trade, should play in supporting the country's export drive is examined, including the provision of long-term credits. In so far as the small business firm is concerned, the Report recommends that banks should be ready to offer term loan facilities within reasonable limits, having due regard to their liquidity requirements as an alternative to a running overdraft for creditworthy industrial and commercial customers. Reference is made to certain special problems about the provision of finance for the commercial development by small concerns of new inventions and techniques. Such problems could be very well overcome, it is suggested, by the formation of an Industrial Guarantee Corporation, backed by the Government. The main object of this body would be to facilitate the commercial exploitation of a technical innovation, although not the initial stages of research and development which might be required. The Corporation would, as we see it, guarantee, for a commission, an agreed proportion of loans made by existing financial houses to borrowers wishing to finance novel processes or new types of products. The Report states, "We believe that a Corporation operating on these lines could make a real contribution to the ability of British industry to compete in world markets, and we recommend that the Government should consider this proposal in that light."

The whole Report is worthy of serious study by business men and the industrial world in general. The final chapter of the Report explains why the Committee does not set out a definite list of recommendations but merely stresses the main ideas which it considers should emerge from a careful study of the report. It does stress that the external assets and liabilities of the country are an integral part of its economy and its financial system. The United Kingdom is the financial centre of the Sterling Area, and as such must always bear in mind that it cannot by its own choice abdicate the responsibilities such a financial centre entails.

Out of the MELTING POT

Some Evidence

THE small angle scattering technique of X-ray examination originally appeared to be capable of giving unequivocal answers in connection with the detection of inhomogeneities (small particles, clustering of atoms, dislocations, vacancies, etc.) lying between 10Å and 1,000Å in size, without the uncertainty as between small crystallite size and internal strains in large crystallites which is encountered when, for example, the line-broadening effect is used. The small angle scattering technique has since been considerably bedevilled by the discovery of the phenomenon of scattering due to double Bragg reflection, not to mention multiple scattering, but nevertheless can, in appropriate circumstances and with the appropriate treatment of the measurements, be made to yield useful information. In other cases, what in the past would have been regarded as small angle scattering is now considered to be, in fact, due to the double Bragg reflection process (reflection taking place successively on the planes of the same family in two slightly-disordered domains within the same grain). Thus, in particular, it has been shown that the majority of scattering from cold-worked metals can be explained by the double Bragg reflection process. At present, studies of small angle scattering (whether true or of the double Bragg type) are proceeding in parallel with applications of these techniques to the study of various structural problems, such as those encountered in quenched and irradiated metals, in connection with dislocations in deformed single crystals, in cold-worked metals and, last but not least, in metals subjected to cyclic stress (fatigued metals). This may be considered as a rather ineffectual undertaking of the uncertain leading the half-blind, but in so far as some progress is being made, both the techniques and the understanding of the problems are likely to benefit, though admittedly the former more than the latter, which, fortunately, have other means, such as, in particular, electron transmission microscopy, to call upon for help. Nevertheless, there is no reason to be other than duly grateful to the small angle scattering techniques for such bits of information as, for example, that the evidence obtained favours the view that, in fatigue stressed metals, the formation of subgrains, while probably necessary for the propagation of a fatigue crack, is not sufficient either for its formation or propagation; that recrystallization does not occur on annealing following cyclic stress of the order of one-quarter the yield stress; and that no evidence exists for widespread formation of voids in fatigued specimens.

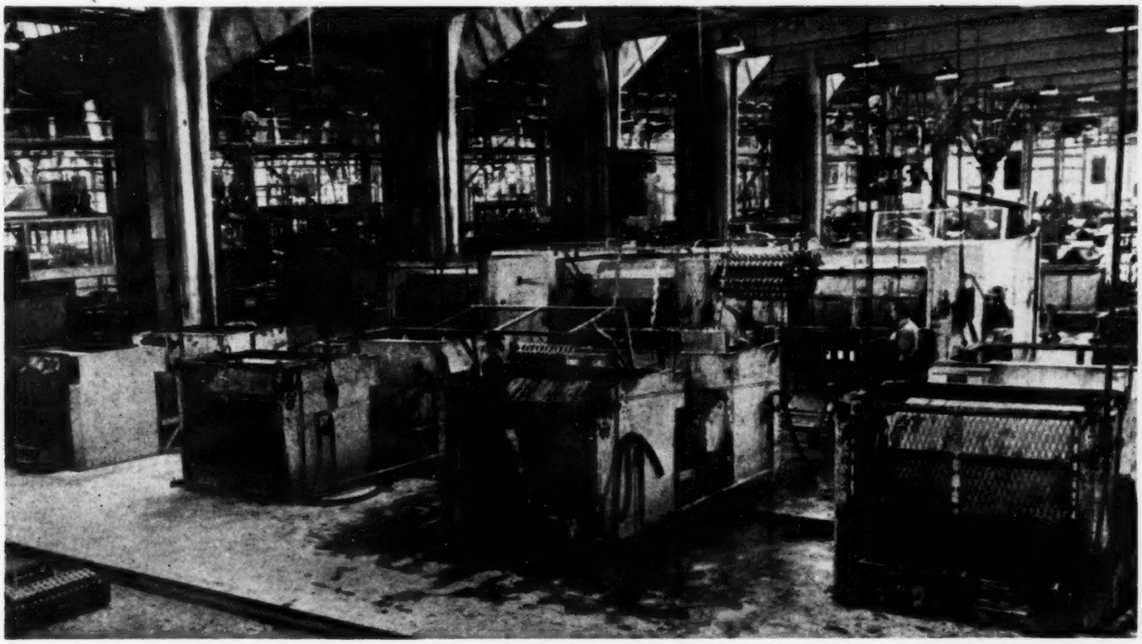
"Necessities"

IT was in a more realistic age, which set a greater value upon consistency, that the remark was coined about necessity being the mother of invention. The matter is not so simple now that we are farther away from first principles and prime necessities. Freedom from want has not, however, meant freedom from invention; on the contrary. A new approach to a study of the why and wherefore of inventions is, therefore, considerably overdue. Such a study, like any other investigation these days, will have to start with a survey of published information. Whether, again, like so many other investigations these days, it will find the results of such a survey useful, remains to be seen. What, for example, could it possibly make of the following quotation, published as a quotation from some unspecified source, in a recent issue of the *Battelle Technical Review:* "In more primitive times was coined the aphorism that necessity is the mother of invention. Man needed wheels, so he devised them. To-day, research is the mother of invention, because we do not need the things we do not have. We just discover, through our intellectual curiosity in technological fields, that we can make things we never had before and never missed. The premium in our industrial civilization is not on what we need, which requires an inventor, but on what we can make, which research workers are revealing every day." It would appear from the above that the question as to what is a necessity, which question was an idle one in sterner times, is no longer one that can be omitted from any investigation into the subject, if only because the absence of any necessity—"things we never had before and never missed"—is now claimed to be the cause (it could hardly be claimed to be the *reason* in more senses of that word than one) why we nevertheless finish up by having them.

Small Contribution

JUDGED on the basis of research and interest, very finely divided metal powders come a poor third, behind thin metal films and metal whiskers. In the circumstances, even a small contribution to the study of finely-dispersed metal powders must be received with gratitude. The production by mechanical comminution of a powdered metal having a sufficiently uniform fine particle size of the required order (10^{-5} cm. or less) is difficult. Because of this difficulty, the aluminium powder, which formed the subject of the particular contribution, was prepared by a method described, significantly enough, in 1933. In this method, a small amount of aluminium is evaporated from a tungsten filament placed at the centre of an 8 cm. diameter glass vessel. This vessel is first evacuated and degassed, and then argon, helium, or hydrogen is admitted to the required pressure (from 1 to about 30 mm. of mercury). The aluminium evaporated under these conditions is deposited in the form of very small particles on the water-cooled wall of the vessel. The powders obtained in this way were examined in an electron microscope to determine their particle size distribution, and their tendency to oxidize was also studied: some of the deposits were spontaneously flammable in air. The mean particle size of the powders at first increased with increasing pressure of the inert gas atmosphere in which the aluminium had been evaporated. At very low pressures, of course, the metal atoms reached the wall without collisions and formed a mirror deposit. At pressures below 1 mm., the particle size was below the resolving power of the microscope (about 10^{-7} cm.). At pressures between 20 and 30 mm., the increase in particle size with gas pressure slowed down, the particle size finally becoming constant. This ultimate constant particle size was different for the different gases, being largest for argon and smallest in the case of powders deposited in helium, with that of powders deposited in hydrogen being intermediate. The fact that all the powders deposited had a spherical particle shape will be investigated in connection with the light it may throw on the mechanism of the formation of a solid phase.

Skimmer



Section of the grinding department of the Volkswagen works showing fourteen Roto-Finish machines banked in pairs. A technique has been developed here for polishing bumper over-riders in a single stage. After 2½ hr. treatment they have a sufficiently high finish to be plated directly

Machining in Barrels

By D. J. FISHLOCK

ARE we now approaching the zenith in the development of barrelling techniques? There are two distinct schools of thought: the ayes and the noes. Barrelling, also known under a host of equally descriptive titles, has come a long way from its humble origins, traced by Kellard[1] back to 1790. Even in its crudest form it is an entirely logical method of, for instance, removing burrs and flashes from small, compact items which will tumble without damage, while such refinements as fixture barrelling, which are often regarded as recent innovations, date back to the 19th century.

Several reasons are discernible for the slow evolution of barrelling—and, indeed, for the reluctance to accept the modern developments which is still apparent in many quarters. Foremost, probably, is the fact that it was invariably a very noisy process, chiefly owing to the use of unlined steel barrels. It was also regarded as a crude and unskilled operation on which the least capable operatives could be employed. Contributory factors include the free use of water, and the use of a large variety of materials which were unpleasant to handle, as barrelling media; for many years mineral oil and sand have been recommended media for deburring and smoothing ferrous and brass castings, while cow dung and coke dust has been used with considerable success for polishing by one concern—of which more anon. Couple all of these factors with a tendency, on the part of those few who, by dint of perseverance, empirically adapted the techniques to achieve a greater versatility, to die with their hard-won acumen, and the reason for the slow development becomes clearer.

It was during World War II, however, that a new approach to barrelling was engendered. It was recognized that herein lay a simple and natural mass production technique restricted largely by lack of correlation of the innumerable individual process variables. Simultaneously, new plant was devised and media prepared and formulated on a more scientific basis. The results, when these developments were applied systematically, were extremely encouraging and precision barrelling thus slowly emerged.

The present state of development of what might be termed general-purpose precision barrelling involves close co-operation between supply house and customer. The supply house, on the basis of its considerable experience, will develop a technique for a given component and then continue to supply media. It is an interesting point in this connection that potential customers often select their most awkward problems, e.g. most heavily burred or rustiest components, for the trials, in the erroneous belief that if barrelling can cope with them it will cope with any relevant production exigency. In actuality, however, this practice does risk misleading the supply house, which has to judge whether the production techniques of its customer are, in fact, as bad as would appear, or whether to modify the barrelling conditions ascertained when estimating the cost, etc., of a process. A few more enterprising — and usually large — concerns prefer to evolve their own techniques but continue to purchase the proprietary media, since these have now reached a very high state of development, particularly with regard to the constancy of quality so essential to high outputs. Then, very occasionally, the supply house is asked to develop some quite unusual barrelling machine to cope with a special problem: instances include machines for deburring helicopter spars over 30 ft. long.

Barrelling should, strictly speaking, be regarded as a machining rather than a finishing operation; 60 to 70 per cent of its total application is concerned with deburring alone. The tendency, however, is still to regard it as a finishing process, chiefly presumably since it is a "wet" process and uses chemicals. With modern plant, however, it is eminently practical to install most barrelling processes at the point most convenient for flow production, although there is also much to be said in favour of an entirely separate and

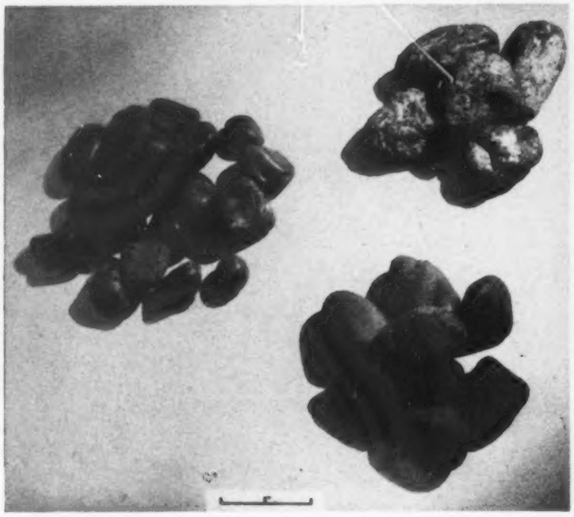


Fig. 1a—Three different grades of synthetic barrelling chips based on aluminium oxide

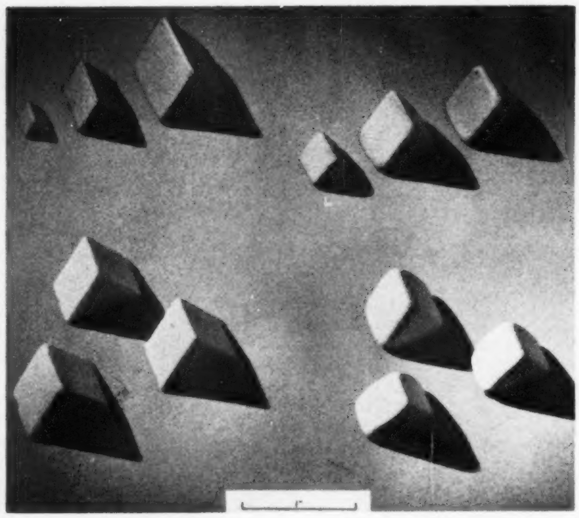


Fig. 1b—Synthetic pre-shaped barrelling chips also based on aluminium oxide and moulded or extruded in bar form before being cut into chips

correctly laid-out barrel finishing shop. Similarly, it pays dividends to ensure there are intelligent operatives either working or directly responsible for barrelling operations so that the considerable advances of recent years, both in technique and in media, can be fully utilized.

Barrelling Media

By this is meant the chippings which, in nearly all cases, constitute a large proportion (50-85 per cent) of the barrel load. They play several roles, including the separation of components and the addition of bulk and weight to the tumbling mass; they also act as the cutting or burnishing medium (with or without added abrasive powder) for which role their shape is of especial importance. Media can be grouped into the following categories: natural stones; synthetic media; organic media and metallic shapes.

The first, natural stones, have seen the widest application, the two in general use being felsite—a hard, volcanic rock, and limestone, a sedimentary and rather soft rock. These should be relatively cheap, since both are freely available. Unfortunately, felsite frequently contains sulphur, and the sulphur content must be below 0·03 per cent or the rock will cause corrosion during barrelling; moreover, sulphur-free rocks are often rather soft. These rocks, and others such as granite and quartzite, all suffer from the inherent disadvantages of being too brittle, and although at the start of their life they are usually very fast-cutting, this attribute is often ephemeral. In consequence, they are initially tumbled together to a stage where they will display a uniform rate of cut for a reasonable period to avoid undue production fluctuations.

In recent years, though, attention has increasingly been focused on synthetic media, which are almost entirely constituted of abrasive material and do not, therefore, lose their cutting propensity or break up (fracture). Most important by far is aluminium oxide produced by fusing bauxite (Al_2O_3 plus impurities, notably iron) at temperatures above 1,650° C. in an electric arc furnace. At the lower temperatures, a large grain-size, very fast-cutting chip is formed, but at 2,000° C. a markedly smaller grain-size chip is produced which, though much slower, is ideal for many barrelling operations. Cheaper chips can be formed by incorporating other minerals: one consists of 75 per cent silicon dioxide, 20 per cent aluminium oxide, and 5 per cent ferrous oxide; this is fast-cutting and useful for polishing and finishing. The superior hardness—equal to sapphire, or tungsten carbide—and wearing characteristics of synthetic chips, which have been available in this country for some two years, ensure that they will soon largely replace natural stones in this field.

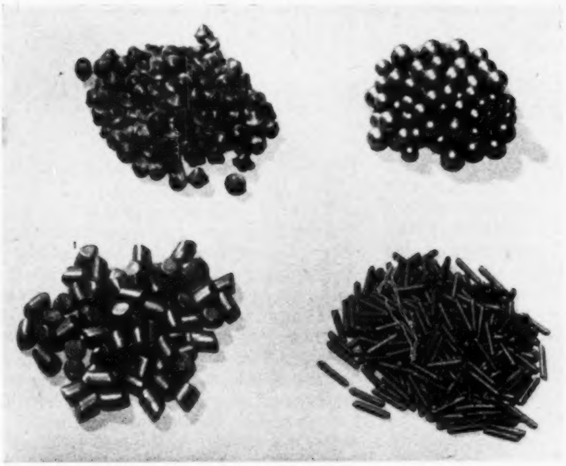
The chips described above are irregularly contoured, Fig. 1a, and, although they tend to wear into pebble shapes, retain a general irregularity throughout their useful life. There is another type of chip, however, the value of which has lately become increasingly apparent. This, the pre-shaped chip, Fig. 1b, is also synthetic, based on aluminium oxide, and either moulded or extruded in bar form and cut into chips of closely controlled dimensions. Two types of pre-shaped chip are available. One is a very hard, ceramic (porcelain) base chip with a low abrasive content, which gives a good deburring action and simultaneously imparts a satisfactory finish. The other is much faster-cutting owing to its much higher abrasive content, but the depreciation rate is greater.

The most useful shapes are those of triangular or square section, in various thicknesses, and the diagonals, *vide infra*. Circumspect selection of shape and size will ensure a greatly reduced chance of them jamming in holes, etc., compared with irregular chips.

Of the remaining two types of barrelling media, only the metallic is widely used to-day. Case-hardened steel shapes, Fig. 1c, usually balls but lately in many exotic forms including pins, cones, double cones, elliptical shapes and diagonals are used for special deburring operations such as where too great a radius must be avoided; sharp corners can thus be maintained within a radius tolerance of 0·002 in. Steel shapes prove peculiarly satisfactory as burnishing or "colouring" media. These require a high surface finish for optimum results, and must be preserved in a rust-inhibitor when not in use. Diagonals, now available in metals such as steel and zinc, or in ceramic, are an especially valuable shape since they offer minimum opportunity for lodging in holes, while their acute angles exert a burnishing action which will penetrate into every corner. Other metals, zinc balls in particular, offer an advantage in cases where the tumbling work may tarnish through bi-metallic corrosion, e.g. in the case of zinc-base die-castings. Organic media are little used to-day for metal, although impregnated wooden squares are currently being developed for polishing plastics. Leather "mousings" or trimmings still find some application; for instance, they are used with Vienna lime as a dry final operation on iron or steel to obtain the highest finish.

Barrelling Compounds

An air of mystique comparable with that associated with bright plating solutions has long surrounded barrelling compounds. While, however, their



Above: Fig. 1c—A variety of steel shapes for barrelling—double cones, balls, diagonals and pins

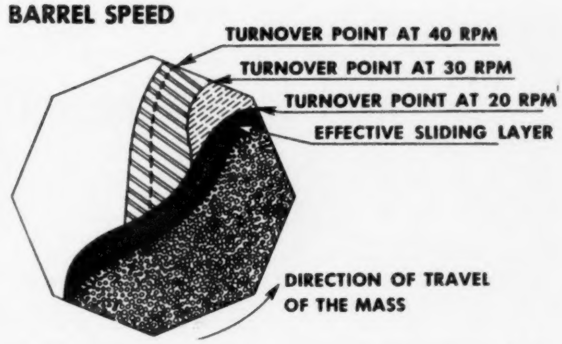


Fig. 2—Effect of barrel speed on movement of charge

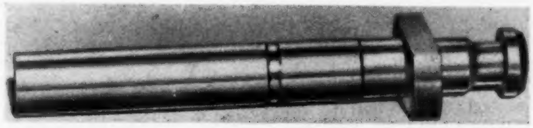


Fig. 3—Fuel injection pump component is barrel machined to a 2μ finish and to an accuracy better than 0·0001 in. by the Almco-Supersheen process, at one per cent of the cost of conventional finishing

influence on and importance to modern barrelling is considerable and undisputed, they are simply mixtures of usually soluble and invariably well-known compounds or materials, the function of each of which is—or should be—clearly definable.

Compounds fall into two categories—those that contain abrasives and those which are completely soluble, i.e. cutting and non-cutting compounds, respectively. Both types are based on a mixture of soluble constituents, which range in number from one or two to ten or twelve. The essential ones include alkalis — phosphate, metasilicate, carbonate, etc.—which function mainly as detergents and *p*H buffers, and sometimes as peptizing or dispersing agents; sodium carbonate also helps to keep the mixtures dry and free-flowing. Surface-active agents are invariably incorporated, as the foam generated has a marked influence in reducing the harshness of the tumbling action. It is possible, too, in immersed barrelling where the solution containing the compound is used for several batches, to control the amount of compound present on the basis of the size of bubble in the foam which forms; dilution and loss of compound causes the bubbles to increase in size and become less stable. Sequestering agents — principally hexa-metaphosphate but sometimes chelates—usually appear in compounds designed for use in hard water areas where they redissolve metallic soap scums; this is of particular advantage in burnishing. Occasionally, however, it is desired to coat the chips with a film which will reduce their cutting action, and one way of achieving this is to use limestone chips with soap solutions, when an insoluble lime-soap film will form on each chip.

The values of nitrogenous compounds, such as nitrates and ammonia, appear to have been long appreciated—the latter is widely employed in hand metal polishes—and these are undoubtedly the cogent ingredients of the dung mentioned earlier as a barrelling media. Again, corrosion inhibitors, of which chromates are the most important, are often needed, although the alkalis assist with ferrous components, while metasilicate specifically inhibits the corrosion of aluminium. Finally, there are the special acidic compounds which give solutions of a *p*H between 1 and 6 whereby the removal of corrosion products, and even heat-treatment scales can be facilitated. In such compounds the requirements of a solution which is both relatively harmless to the skin and has satisfactory detergent properties must be married. They are based on weakly ionized salts such as sodium bisulphate or phosphates, together with acid-stable wetting agents; such solutions introduce very little risk of hydrogen embrittlement.

Turning to the "cutting" compounds, we find these loaded with a variety of abrasive powders designed to function either directly, by coming between the chip and the component, or indirectly by removing films from, and opening up the surfaces of, the chips. Abrasives also tend to become embedded in soft media such as zinc shapes, which then function similarly to a grease bob. The abrasives chiefly used include silicon carbide and dioxide, aluminium oxide, garnet, corundum and emery. Grades range from the finest alumina flow to grits as coarse as 60 mesh, but sizes smaller than 240 mesh are used only for a few specialized applications. By careful selection of the abrasive, soft metals such as zinc or aluminium alloys can sometimes be brought to a high surface finish, e.g. suitable for bright plating, in a single operation. This calls for an abrasive which cuts well initially but breaks down to a progressively finer grade as the operation continues. Pumice is one abrasive which breaks down in this way, although the material must be chosen with care since it is a volcanic ash, and sulphurous grades can prove inimical.

There is nothing complicated basically about the composition of barrelling compounds then, but it must be emphasized that there are pitfalls awaiting the unwary who seek to formulate their own compounds. These relate chiefly to the creating of high pressures in the barrel, and to corrosion of the work. The services of a reputable supply house thus remains a *sine qua non*, while further confidence may be engendered by one prepared to disclose the composition of its compounds.

Barrelling Mechanism

The simplest and most widely used type of tumbling unit consists essentially of an octagonal section barrel which is fairly slowly rotated. This is loaded with free-tumbling components and a cutting media in a ratio, and to a depth, which are both critical and ascertainable only empirically. Additions of water and chemical mixtures termed compounds are also made. This gives seven basic variables: (1) Type and size of chip. (2) Type of compound. (3) Height of load in barrel. (4) Ratio of chips to components. (5) Height of water level. (6) Speed of rotation. (7) Duration of operation.

It is by exercising full control over these variables that the techniques known as precision barrelling processes have emerged from the mass of uncorrelated data on the subject.

The roles played by the various media are now generally understood, but there is still some controversy over the "cutting down" mechanism itself. One, the less widely accepted hypothesis, assumes that there is a relatively slow random motion in the centre of the mass, wherein the bulk of the action occurs; this is said to be

(*Continued on page* 65)

Atomic Progress

Thermal Characteristics of Uranium Dioxide

BY early 1961 the U.K.A.E.A. plans to build a reactor experiment known as A.G.R. The aim of this experiment is to develop a new series of graphite moderated gas-cooled reactors having much higher performance than the Calder Hall type nuclear power stations now under construction in the United Kingdom. This will mean reduced capital costs and improved fuel utilization. In place of the magnesium-clad uranium metal fuel elements of Calder Hall and the early commercial stations, uranium dioxide pellets will be enclosed in beryllium tubes. It is expected that maximum can temperatures will be achieved about 200°C. higher than for Calder and about five times as much heat will be extracted from the fuel. To achieve this, enriched uranium will have to be employed (containing about $1\frac{1}{4}$ per cent of fissionable U_{235}).

One of the major advantages of uranium dioxide over uranium metal is the dimensional stability of the oxide under irradiation. Uranium dioxide pellets are hard and brittle and possess low resistance to thermal shock. They cannot, therefore, be relied upon to act as a stress-bearing component in the reactor. Uranium dioxide also possesses a very low thermal conductivity which leads to high fuel centre temperatures in fuel elements in service. These disadvantages can, to some extent, be overcome by the use of fuel elements of small diameters and of high density. In this article the thermal characteristics of uranium dioxide are considered.

Formation of Oxides

Uranium will form a range of oxides, of which $UO_{2\cdot0}$ is one. Uranium dioxide may be prepared in stoichiometric form ($UO_{2\cdot0}$) by reduction of higher oxides in hydrogen. On exposure to air the oxygen content increases, even at room temperature, by an amount governed by the particle size and time of exposure, the non-stoichiometric oxide so formed may have compositions typically within the range $UO_{2\cdot0}$ to $UO_{2\cdot25}$. The effect of variations from the stoichiometric composition are important in fabrication, in their influence on properties and on irradiation behaviour. For example, Canadian workers[1] report that preliminary measurements of thermal conductivity of uranium dioxide of composition $UO_{2\cdot16}$ at 70°C. is only about half that of stoichiometric UO_2 under the same conditions. Recent determinations at A.E.R.E.[2] give values of thermal conductivity of 0·0078 cal/cm^2/cm/°C/sec. at 800°C. and 0·00058 cal/cm^2/cm/°C/sec. at 1,200°C. (values corrected to theoretical density) for stoichiometric $UO_{2\cdot0}$ of 95 per cent theoretical density. Apart from the variations related to stoichiometry and density, fabrication techniques can influence the values of thermal conductivity. Thus, at 70°C., swaged UO_2 is reported[1] to have a thermal conductivity of only 40 per cent of that of sintered UO_2 of similar density under the same conditions.

Thermal Conductivity

Berg, Flinta and Seltorp[3] have made thermal conductivity measurements on both irradiated and non-irradiated sintered UO_2. Four types of cold-pressed and sintered UO_2 were employed:—

(1) $UO_{2\cdot17}$ of density 10·2 gm/cm^3; sintered at 1,800°C. in an H_2 and H_2O atmosphere.

(2) $UO_{2\cdot03}$ of density 10·0 to 10·1 gm/cm^3; sintered at 1,600°-1,620°C. in a cracked NH_3 atmosphere.

(3) $UO_{2\cdot08}$ of density 10·2 to 10·3 gm/cm^3; sintered at 1,550°C. in a cracked NH_3+H_2O atmosphere.

(4) $UO_{2\cdot08}$ of density 10·44 to 10·45 gm/cm^3; sintered at 1,680°-1,720°C. in a cracked NH_3 atmosphere.

The uranium dioxide was prepared by calcination of ammonium uranate to give "UO_3," followed by reduction to stoichiometric UO_2 and controlled oxidation in air to a non-stoichiometric form.

In the first series of tests, annular UO_2 pellets of types 1, 2 and 3 were canned in stainless steel tubes with an 0·1 mm. radial clearance. A tungsten rod passing through the central hole was electrically heated to obtain large radial temperature drops through the specimen which produced high thermal stresses. Platinum-platinum/rhodium and tungsten-molybdenum thermocouples located near the inner and outer surfaces of the UO_2 were employed to observe the radial temperature drop. Values of the average thermal conductivity between the two thermocouple positions are reported which show wide variations with temperature between 0·02-0·06 W/cm°C., for specimens canned in stainless steel tubes. Type 1 oxide canned in aluminium exhibited a very low thermal conductivity of about 0·007 W/cm°C. after a few thermal cycles. This is comparable with the value for powder and the authors suggest that it is due to the UO_2 cracking under thermal stresses, whereas with the stronger canning material, stainless steel, there is some restraint which may reduce or prevent cracking.

At temperatures above about 200°C. the $U_{2\cdot08}$ (type 2) exhibited lower values of thermal conductivity than the $UO_{2\cdot17}$ (type 1).

These workers also determined thermal conductivity in the absence of thermal stresses using a technique employing axial heat flow. Tests were made on non-irradiated oxides of types 1, 2 and 3 and on similar material irradiated to 2×10^{16} and 5×10^{17} nvt. This level of irradiation had no effect on the thermal conductivity at temperatures up to 250°C. No results are given for higher temperatures.

In the third series of tests, the Swedish workers measured the variation in thermal conductivity of $UO_{2\cdot17}$ (type 1) and of $UO_{2\cdot08}$ (type 4) during irradiation. The irradiation rig was designed so that the average specimen temperatures could be held in the range 250°-300°C. independently of reactor power and shut downs. The radial heat flux produced by $1\cdot8\times10^{12}$ neutrons/cm^2 was used for measuring the thermal conductivity. At 300°C. the thermal conductivity was initially 0·02 W/cm°C., in agreement with out-of-pile measurements. At a dose of 10^{18}n/cm^2 type 1 oxide showed a rapid decrease in conductivity to 0·005 W/cm°C. The type 4 oxide did not show a drop in conductivity even after 3×10^{18}n/cm^2. No information is given on the structures after irradiation or on the temperature gradients. In the absence of such data it is not possible to deduce the reason for the reduction in thermal conductivity. The authors suggest that the large change may be due to the release of internal stresses due to sintering by temperature cycling. A more likely cause of the decrease is that the more extensive thermal cycling of the type 1 samples eventually caused the pellets to crack.

Cracking and Grain Growth

Data on the appearance of irradiated uranium dioxide pellets irradiated with centre temperatures in the range 800°-2,500°C. are given by Robertson *et al.*[4] Pellets normally exhibit radial cracks, and in some instances circumferential cracks also. The fragments are quite large and there seems to be no tendency to powdering. The appearance is consistent with the cracks being due to thermal stresses. Small pellets irradiated at low ratings may remain intact.

Because thermal conductivity and axial temperatures are difficult to determine separately, the parameter $\int_{\text{surface}}^{\text{centre}} k(\theta)\,d\theta$ is often used to compare the behaviour of specimens of different diameter, enrichment, density, heat-

(*Continued on page 60*)

Reviews of the Month

NEW BOOKS AND THEIR AUTHORS

MAGNESIUM

"The Physical Metallurgy of Magnesium and its Alloys." *By G. V. Raynor. Published by Pergamon Press Ltd.*, 4-5 *Fitzroy Square, London, W.*1. *Pp.* 531. *Price* 75*s.* 0*d.*

AS Professor Raynor tells us, magnesium is a typical metal, but in one sense he himself has now converted it from typical to unique, by making it the only metal which has had, in a single volume, all its aspects considered in the most fundamental terms provided by current knowledge of the solid state. In this respect, his book on the Physical Metallurgy of Magnesium and its Alloys is particularly satisfying because the task Professor Raynor has now accomplished is one which many metallurgists have felt for some time should be tackled, though few could themselves call upon the courage, industry and depth of knowledge which has clearly been brought to bear by the author.

Forward-looking industrial metallurgists, who hope that the fundamental work on metals and alloys in which Professor Raynor has played an important part might point the way to better materials, may perhaps experience a tinge of regret that magnesium was chosen for this study instead of some metal of greater engineering importance. but one can see from the book itself that the fundamental nature of the metal and the large body of data available might well have made magnesium by far the most suitable element on which to try out the more purely scientific approach to metallurgical writing.

The result is not a book for the casual seeker after knowledge—the reader is required to work hard from page eight onwards. In one or two places, indeed, it is difficult not to feel that the author has been almost over-generous with information, as for instance in the first paragraph of the section on diffusion, which includes a detailed, if potted, account of the manufacture and separation of a radioisotope of magnesium.

The difficulty which faces any author of a book about a single metal is how much knowledge of general metallurgy he should assume in the reader. If he does not take a large part of what he wishes to cover as already known in general terms. and confine himself to the particularities of his subject, his book will become a treatise on metallurgy in general and extremely bulky into the bargain. Professor Raynor is obviously aware of this problem, and has tried to solve it by giving a very brief summary of the general position before introducing any new topic. The level to which he wishes to penetrate, however, is invariably deep, and by thus starting in the shallows he makes the descent very steep; so steep, in fact, that the reader's head tends to go under. It might perhaps have been better to assume that anyone who can swim well enough to follow the author through his subject could have dived straight into the deep water rather than having to walk so rapidly down the steps at the shallow end.

Though its essential purpose is to present a rational account of the fundamental nature of magnesium and its alloys, the book contains a considerable amount of information of technological importance. The chapter arrangement may not make this point immediately apparent, but a useful index leads the enquirer to the information sought.

It is to be hoped that Professor Raynor has started a new fashion in metallurgical text books, because the infusion of basic science into technology which will result if others follow his lead, may have far-reaching results in materials engineering.

M. K. McQ.

FATIGUE

"Metal Fatigue." *Edited by G. Sines and J. L. Waisman. Published by McGraw-Hill Book Co.*, 95 *Farringdon Street, London, E.C.*4. *and New York. Pp.* 415. *Price* 97*s.* 0*d.*

THE preface indicates that this book had its origin in a private conference held in the Engineering Department of the University of California, in 1953. A perusal of literature references suggests that from among the sixteen authors only F. A. McClintock and R. E. Peterson have bothered to make significant additions to their contributions as originally presented. The editors, in their "Guide to the Literature," fail to mention any book published after 1954 and ignore the massive 1956 Proceedings of the Fatigue Conference organized by the Institution of Mechanical Engineers.

The book is generally inferior to the British "Metal Fatigue," (Ed. J. A. Pope) (reviewed in METAL INDUSTRY, p. 445, 29 May 1959) which deals with all the topics treated and a few more besides. Special mention may be made of the Introduction and the section on Fatigue Failure Mechanisms as well-intentioned, even if partially out of date, and of the chapter on Statistical Techniques (by McClintock) which is very readable.

Written by American engineers for American engineers and overwhelmingly with American examples and terminology, there is little that this book can offer to well-informed British metallurgists. One curious feature is an acknowledgment of expert help in "unifying the style of technical writing." Apart from the results as judged by the curious expressions which remain in the text, this is perhaps indicative of the limited responsibility which was accepted by or imposed upon the editors. This is not a good example of publishing enterprise.

T. B.

ALUMINIUM CASTING

"Aluminiumgusz in Sand und Kokille." (*Aluminium Sand and Die Casting.*) *By Roland Irmann. Published by Aluminium-Verlag G.m.b.H., Düsseldorf. 6th revised edition. Pp.* 302. *Price DM.* 42.

THE fifth edition of Dr. Irmann's book appeared in 1952. It was widely and very well received, evidence of this being provided, *inter alia*, by the publication of a French translation. This favourable reception has been one of the factors that moved the author to undertake the preparation of the present revised sixth edition. Another factor, of course, was the new developments that have taken place during these last seven years in aluminium foundry practice. They include developments in melting and refining practice, a new German (DIN) standard specification for aluminium casting alloys which is used as a basis for the treatment of this subject in the book under review, developments in moulding materials and casting processes, in gating practice, in methods of examining and testing castings, and in surface treatments, and also the growing interest in the high-temperature properties of cast aluminium alloys.

All these have been taken into consideration in preparing the up-to-date revision, without allowing them, however, to modify the basic, provenly successful nature of the publication, which still remains an admirable guide to its title—aluminium sand and die casting—to which should be added the word "practice." Theory and speculation—so temptingly easy in connection with certain aspects of the subject —have been kept in check.

Deprived, like other writers on complex technological processes, of multi-dimensional ways and means of presenting the subject matter, Dr. Irmann has succeeded in presenting it in a series of chapters compounded to impose the minimum of disjointing and to avoid overlapping.

The first of these chapters deals, quite briefly, with the material used for aluminium casting: pure aluminium and the standard aluminium casting alloy compositions, with the production of aluminium casting alloys, and with the recovery of aluminium alloys from scrap. In the next chapter the

author discusses the effect of the melt and of melting practice and of the subsequent solidification on the soundness or otherwise of the casting, and describes and illustrates the various types of defects that may be encountered. A description of the "Telegas" apparatus in the section dealing with methods of determining the gas content of aluminium melts provides one example of the up-to-dateness of the book.

The main groups of aluminium casting alloys dealt with in the next chapter are considered from the point of view of their casting properties and such properties as machinability, weldability, durability, and adaptability to surface finishing. All this leads, in the second half of the chapter, to a general discussion of the choice of the type of casting, design, etc. The headings of succeeding chapters: melting equipment and temperature measurement, treatments of the melt for purification and grain refining, sand casting, die-casting, fettling and surface treatment, repairs to castings, mechanical properties and testing, and design aspects of castings, are all sufficiently indicative of the contents of these chapters.

It ought to be mentioned, however, that the chapter on sand casting includes a section on sand and sand testing, and also some brief accounts of the Croning, Shaw, and plaster mould (Antioch, Alcoa) casting processes, and of the CO_2 process. In the chapter on die-casting, a feature of the book—the wealth of illustrations—really comes into its own, with photographs and diagrams of numerous examples of dies, cores, die assemblies and of machines for operating them, easily predominating over the text. The chapter on mechanical properties and testing does not attempt, as happens sometimes in similar circumstances, to describe the mechanical properties of aluminium casting alloys (these properties are listed in a detailed table in an appendix), but rather concerns itself with the various types of test pieces, methods of casting them, the effect of the solidification conditions on the mechanical properties in different regions of a casting, with creep and fatigue properties, and with non-destructive testing.

The appendix includes, in addition to the table of mechanical properties already mentioned, a list of casting defects with their causes and cures, a classified bibliography of the literature (most of it post-1952), and a subject index.

Seven years should be a sufficiently long period to prevent the more parsimonious purchasers of the fifth edition from wondering whether buying the revised sixth edition is worth while. It is. Those, on the other hand, who do not possess the earlier edition and whose German is adequate—or even, in view of the numerous illustrations and the very easy style, a little less than adequate—had better start wondering whether all these years they could not have made good use of it, and should then decide not to wait until the publication of the seventh edition.

A. B.

Atomic Progress—*continued from page 58*

rating and fabrication history. [K (θ)= thermal conductivity of uranium dioxide at temperature θ.] Specimens with values of $\int_{400^\circ\mathrm{C.}}^{\mathrm{centre}} k\ (\theta)\ d\ \theta$ exceeding 37 watts showed central areas of grain growth. Columnar grains were often produced in the steep radial temperature gradients. Circumferential cracking normally occurred just outside this region. There is limited evidence that stoichiometric UO_2 may be less prone to grain growth than oxygen-rich material which is reflected by the latter exhibiting grain growth at lower temperatures than the former. The calculated value of $\int_{\mathrm{surface}}^{\mathrm{centre}} k\,(\theta)\,d\,\theta$ for centre melting at 2,750°C. is 49 watts/cm; specimens with values of the integral up to 40 watts/cm. did not appear to have melted.

Swaged stoichiometric UO_2 appeared to sinter during irradiation at temperatures as low as 900°C. compared with a temperature of 1,750°C. required to sinter the material normally.

Murray *et al*[5] suggest that during irradiation the fragments of uranium dioxide will be held in place by the can and resinter. Fresh series of cracks would form at each large thermal cycle, probably in areas where there is already internal stress due to the presence of fission product gases. The areas near cracks would become depleted of fission product gases and each set of cracks would occur in different regions. Murray *et al* believe this is the cause of the fibrous radial structure in irradiated non-stoichiometric uranium dioxide. In the light of the results obtained on swaged UO_2 this seems a feasible process. An alternative explanation is that columnar grain structures develop as a result of grain growth and diffusion of fission products gases leads to precipitation of bubbles along the grain boundaries. The results of Canadian work[4] indicate that in practice both mechanisms may be operating simultaneously.

Summarizing, it can be seen that the thermal characteristics are markedly dependent on composition. Irradiated samples show extensive cracking attributed to thermal stresses, which can lead to reduced values of thermal conductivity. If centre melting is shown to be undesirable, and this has yet to be demonstrated, this could impose a design limitation on fuel elements.

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1 G. H. Chalder *et al;* Second Geneva Conference Paper. A/Conf. 15/P/192.
2 P. Murray *et al;* Second Geneva Conference Paper. A/Conf. 15/P/318.
3 K. Berg *et al;* Second Geneva Conference Paper. A/Conf. 15/P/141.
4 J. A. Robertson *et al;* Second Geneva Conference Paper. A/Conf. 15/P/193.
5 P. Murray *et al;* Symposium on Fuel Elements. Paris Nov. 1957. "Uranium Dioxide as a Reactor Fuel." Document H34440 X.

Men and Metals

An appointment is announced by Holman Brothers Ltd. of **Mr. James L. Ritchie,** B.Sc., as sales director, with responsibility for the direction of the Holman group's sales organization at the Camborne headquarters and in the U.K. and overseas. He has now become an associate director of the company.

Indian Oxygen, a British Oxygen Company subsidiary, has appointed **Mr. A. K. Sen** to be its managing director, and **Mr. P. C. Kavanagh,** its assistant managing director.

The constitution of the board of the Imperial Aluminium Company Limited has been announced as follows: — From Imperial Chemical Industries Limited: **Dr. James Taylor** (chairman), **Mr. Berkeley Villiers** (managing director) and **Mr. Michael Clapham.** From the Aluminum Company of America: **Mr. DuBose Avery** and **Mr. F. J. Resch.** Dr. Taylor has been a member of the main board of Imperial Chemical Industries Limited since 1952. Mr. Berkeley Villiers has been commercial director of I.C.I. Metals Division since 1953. Mr. Michael Clapham has been joint managing director of I.C.I. Metals since October 1952. Mr. DuBose Avery has been elected a vice-president of Alcoa International Inc., and Mr. F. J. Resch was formerly chief industrial engineer for the Fabricating Division of Alcoa's Tennessee operations. He has been with the company since 1934.

Appointed as assistant managing director of Oldham and Sons, Manchester, **Mr. O. Oldham** is the son of the chairman, **Mr. J. Oldham. Mr. J. Dowse** has been appointed production director, and **Dr. C. D. J. Statham** as sales director.

Titanium Technology

This article which is a condensed version of a memorandum issued by the Battelle Memorial Institute, reviews some of the more recent developments in the techniques of melting, heat-treatment, rolling, extrusion, forging and machining of titanium alloys

FOUR major developments now under way are expected to reinforce and augment the advantages offered by titanium for military aircraft and missile applications, namely: (1) Development of uniformly heat-treatable high-strength alloy sheet; (2) development of sandwich construction techniques; (3) development of processing procedures and equipment to broaden the types of forms and shapes in which titanium alloys are available (thin sheet, extrusions, castings); (4) development of weldable alloys which will maintain useful strength up to 500-600°C. and of alloys with room temperature strength of 100 tons/in^2, or greater.

Melting

Skull melting, a technique still in the development stage, shows considerable promise for producing both ingot and shaped castings. In the skull melting process, the molten pool of titanium is contained in a thick skull of solid titanium on a water-cooled copper or a graphite hearth. The skull-melting furnace may employ fixed carbon or tungsten electrodes, or consumable electrodes made by welding together compacted sponge, titanium ingot, or massive scrap. The molten charge is cast from the skull furnace into ingot or casting moulds by a tip-pour mechanism.

Of research interest is the melting of titanium by electron beam methods, whereby the metal is liquefied by a high-energy beam of electrons in a high vacuum. Super-high-purity material results.

Skull melting, using consumable electrodes and water-cooled copper crucibles, now appears to be the most satisfactory melting technique for castings. The Bureau of Mines at Albany, Oregon, uses a furnace with an 8 in. diameter electrode and 10 in. diameter crucible (Fig. 1). At an energy input of 250 kW, 90 to 100 lb. of titanium is available for casting. About 35 per cent of the total weight of metal charged remains in the crucible as skull. Recently, a 15 in. by 15 in. crucible with a pouring capacity of 180 lb. of metal has been put into service.

Techniques for producing titanium castings on a commercial basis would be advanced greatly by development of a suitable expendable mould material. Sound, small castings, having reasonably good surface finish, have been made in expendable moulds of rammed graphite, refractory oxides, or graphite-coated zircon. However, these castings had contaminated skins which adversely affect ductility and impact properties.

For the present, machined graphite moulds offer the best hope for producing quality castings with a minimum of surface contamination. The Bureau of Mines has used sectionalized, machined graphite moulds to produce intricate castings with excellent surface finish and surface contamination normally not exceeding 0·010 in. in depth. The principal disadvantages of machined graphite moulds are the high cost and short life. Mould costs can be reduced considerably by employing the sectionalized, bolted-together moulds. This obviates replacement of the entire mould if one part is damaged or eroded. Mould life may be further extended by using expendable graphite inserts in areas subject to breakage or erosion. It has been reported that such moulds may be used for as many as 50 castings.

Rolling

To get maximum advantage in design of titanium's basic properties, alloys will be required in thin gauges and larger size sheets than have hitherto been available. Until very recently, titanium has been rolled on equipment originally designed for processing steels. The normal practice for unalloyed titanium has been to hot roll on continuous or reversing mills, then to cold roll to finish gauge on strip mills. Alloy sheet is generally sandwiched between steel cover sheets and hot finished by pack rolling in hand sheet mills. It has been necessary to roll the alpha-beta alloys in hand mills so that the material can be cross-rolled to avoid the anisotropy (variation of properties with direction) which would result from rolling in only one direction. Since directionality of properties is less of a problem with the all-alpha and all-beta types of alloys, these alloys could probably be processed to thin sheet by continuous rolling techniques. Several of the titanium producers are investigating straight rolling techniques for alpha-beta alloys. They report that significant progress is being made and are confident that satisfactory techniques will be developed. The practical results of this rolling development work can be seen in Table I, which summarizes the success producers have had in rolling thin gauge material.

Other critical problems remain to be solved if titanium is to achieve its full potential usage in future high performance aircraft. There is some variation in opinions as to what will be required in sheet materials. Typical of the requirements set down by the aircraft industry are: (1) wide thin sheets in gauges of 0·005 in. or 0·010 in. foil in gauges of 0·001 in. to 0·005 in.; (2) maximum sheet dimension of 48 by 240 in.; (3) thickness tolerances of ±5 per cent and a flatness of 1 per cent. More recently, needs for sheet as large as 120 by 360 in. and gauge tolerances of ±2·5 per cent have been indicated.

It is doubtful whether currently used mills will be capable of producing sheet to meet these requirements. New mills specifically designed for titanium will

A—Sight port
B—Sight port
C—Counterweights
D—Electrical leads
E—Electrode slinger
F—Consumable electrode
G—Automatic tilt mechanism
H—Electrical lead
J—Melting crucible
K—Pouring basin
L—Mould

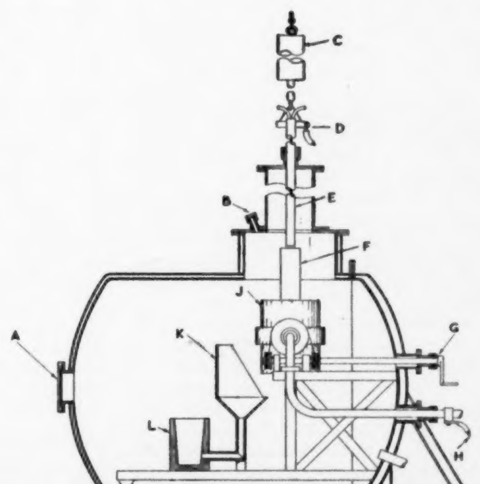


Fig. 1—Casting furnace developed at the U.S. Bureau of Mines, Albany, Oregon Station

TABLE I—MINIMUM GAUGES AND WIDTHS OF TITANIUM SHEET ALLOYS PRODUCED FROM COMMERCIAL-SIZE INGOTS

Alloy Composition, weight per cent	Reported Sheet or Strip Size* in.				
	Cross-Rolling Process			Straight-Rolling Process	
	Gauge	Width	Length	Gauge	Width
Alpha Alloys					
Ti-5 Al-2·5 Sn	0·025	N	N	—	—
Ti-8 AL-2 Cb-1 Ta	0·040	N	N	—	—
Alpha-Beta Alloys					
Ti-16 V-2·5 Al†	0·040	36	96	—	—
Ti-8 Mn	0·012	36	96	—	—
Ti-4 Al-3 Mo-1 V	0·025	36	96	0·075	24
Ti-5 Al-2·5 Cr-1·25 Fe	0·015	48	120	0·0015	6
Ti-6 Al-4 V	0·012	36	80	0·001	6
				0·027	27
Beta Alloys					
Ti-13 V-11 Cr-4 Al	0·030	36	N	0·003	4

"N" designates "not specified", but believed to be 36 in. wide and 96 in. long.
†Classified as an alpha-beta alloy because preferred solution treatment is within the alpha-beta phase field.

probably be required. As a step in this direction, two titanium companies have recently installed Sendzimir-type mills.

Secondary Forging

The jet-engine industry has been, by far, the biggest user of titanium forgings, but increasing quantities of forgings are being used in airframe applications. In the past, airframe forgings have been used in the annealed condition at strength levels, where it was difficult for titanium to compete with high-heat-treat low-alloy steels. Heat-treatable titanium alloy forgings are now available and are being used in several current military aircraft. The heat-treatable titanium alloys now in production offer a considerable weight saving over currently available steel forgings.

Some of the difficulties with early forgings could be attributed to the poor quality of the forging stock. Mill processing and quality control techniques have now improved to the point where this is no longer a serious problem. Hydrogen pick-up and surface contamination can be held at a minimum by maintaining an oxidizing atmosphere in the heating furnace and working quickly. A considerable amount of work has been done on the use of coatings to prevent contamination during heating and forging. Hot-dip aluminium coatings and nickel plates with copper and tin or chromium overlays have been found to be very effective.

Another problem exists as a result of the unusual flow characteristics of titanium and its alloys. As compared to steel, considerably more energy is required to move titanium in the die, especially when thin sections are to be filled. J. J. Russ[1] has presented data showing comparisons of the energy required to forge 4340 steel and titanium alloys to precise dimensions

TABLE II—ENERGY REQUIREMENTS TO FORGE TITANIUM ALLOYS ON A 2500-TON MAXI-PRESS (0·10-IN. WEB THICKNESS)

Alloy	Force, tons/in^2*
Commercially Pure	40-50
Ti-4 Al-4 Mn	75
Ti-2 Fe-2 Cr-2 Mo	75
Ti-5 Al-1·5 Fe-1·4 Cr-1·2 Mo	85
Ti-5 Al-2·75 Cr-1·25 Fe	100
Ti-6 Al-4 V	100
Ti-7 Al-3 Mo	100
Ti-5 Al-2·5 Sn	120

**These figures are to be compared with a requirement of 20 tons/in² for 4340 steel under similar conditions.*

with approximately 0·10 in. web thickness. The 4340 steel required a force of 20 tons/in^2. Pressure requirements for titanium are shown in Table II. These data mean that minimum web thicknesses have to be increased, or web area decreased, if similar titanium and steel forgings are to be produced on the same forging press. Larger capacity equipment would be required to produce the titanium forging to the same dimensions as the steel forging.

Titanium forgings have been produced in a wide variety of sizes by all of the common forging processes. Table III lists comparative design limitations for precision and semi-precision forgings in 4340 steel and titanium.[1]

Extrusions

Some extrusions are currently being used in production model military airframes. These extrusions are being machined to obtain satisfactory surfaces and dimensional tolerances. To meet the airframe producer's requirements, extrusions will have to be available in lengths up to 25 ft., with minimum section thicknesses of below 0·125 in., and ultimate strengths of 85-90 tons/in^2. Surface finish and dimensional tolerance requirements are similar to the current aluminium extrusion specifications. Extrusions will have to be heat-treated to attain the desired strengths. Thus, the extruders face additional problems in developing techniques to heat-treat long extrusions without contamination and warpage.

There is a potential market for titanium extrusions, particularly tubing, for applications outside of the aircraft industry. There is considerable interest in the use of heavy-walled titanium tubes for use in ordnance equipment because of the weight saving possibilities.

While the Sejournet (glass lubricant) process is satisfactory for the production of tubes or shapes which are subsequently machined, grease-base lubricants currently show more promise for producing high-quality structural extrusions. Several companies extruding with greases containing solid film-lubricants such as graphite and molybdenum disulphide have produced extrusions with minimum section thicknesses of about 0·150 in. in lengths of about 15 ft. Surface finishes were held to about 150 to 250 micro in., and dimensional tolerances were roughly 1½

TABLE III—DESIGN DATA FOR SEMI-PRECISION AND PRECISION FORGINGS IN 4340 STEEL AND TITANIUM

Dimension	Semi-Precision		Precision	
	4340 Steel	Alpha-Beta Titanium Alloy	4340 Steel	Alpha-Beta Titanium Alloy
Maximum Surface Area (in^2)	150	100	100	66
Internal Draft Angle	3	3–5	1	1·5–3
External Draft Angle	0–3	3	0–1	0–1
Minimum Web Thickness (in.)	0·125	0·187	0·100	0·100
Minimum Rib Width (in.)	0·187	0·250	0·125	0·125
Minimum Cover Radii (in.)	0·060	0·090	0·050	0·060
Maximum Rib Height	8 × rib width	8 × rib width	8 × rib width	8 × rib width
Minimum Fillet Radii (in.)	0·187	*	0·100	†

**One-half the difference between rib height and web thickness.*
†One-third the difference between rib height and web thickness.

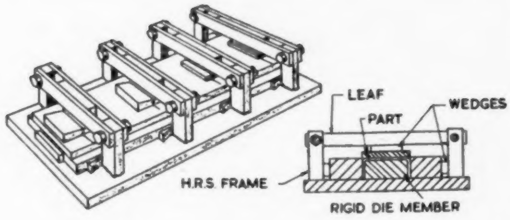


Fig. 2—Hot straightening fixture for airframe parts formed from titanium alloy sheets

to 2 times those specified for aluminium. As section size decreases, however, the acceptable length decreases. Also, up to now, it has been difficult to maintain satisfactory surface finish on extrusions over about 10 ft. long. Extrusions with sections below 0·125 in.—the sizes in greatest demand for airframe applications — are still generally limited to lengths of 10 ft. or less, while the airframe industry requires lengths up to about 25 ft.

Sheet Forming

Progress made in the forming of titanium alloy sheet is perhaps best shown by the markedly reduced rejection rates for formed titanium parts. A major aircraft company, the largest users of titanium alloy sheet, has reported that rejection rates decreased from 17 per cent to about 2 per cent in the 2½-year period ending in December 1956;[2] this was only slightly higher than the rejection rate for parts made from other sheet materials.

This improvement can be attributed to increased production experience, improved heating and forming techniques, the better understanding of forming limitations, more rigid receiving inspection, more stringent in-process quality control, and the improved quality and uniformity of current sheet materials.

Titanium alloys are being fabricated successfully by most of the conventional forming techniques. However, it has been necessary to modify forming techniques because of titanium's peculiar forming characteristics. Since titanium is sensitive to strain rate, slower forming rates are used to obtain maximum formability. Some mild forming of commercially pure titanium and low-strength alloys may be done cold. When more severe forming is required, and for higher strength alloys, it is necessary to go to hot forming to minimize spring back, achieve smaller bend radii, and increase elongation.

Variable spring back, resulting from inconsistency of mechanical properties from sheet to sheet, or even within a single sheet, has been a major problem in forming. Since it is not possible to allow for variable spring back in tooling design, considerable rework is needed to refine contours and meet dimensional tolerances on formed parts unless special procedures are used. This difficulty was first overcome by employing hot creep forming techniques to size accurately parts formed on conventional equipment. The rough formed parts are clamped between steel dies in hot straightening fixtures. The fixtures are then placed in furnaces and heated so that the part is at a temperature of about 500°C. for ½ hr. In this process, sizing and stress relief annealing are accomplished in a single operation. One type of hot-straightening fixture used at North American Aviation is shown in Fig. 2. Hot straightening machines can be hydraulically actuated to maintain maximum pressure throughout the sizing operation. In recently developed machines, tubular electric heating elements are used for heating the platens. In these units, parts to be finish formed on the machines are stress relief annealed, then are placed in the hot dies and held under pressure for 2-10 min.

A notable development has been the achievement of both creep forming and stress relieving operations in a single 5-10 min. cycle. The operation replaces, for many parts, the previous two-step operation of cold or hot forming, requiring one to several minutes, and subsequent stress relieving and sizing at about 500°C., requiring up to 5 hr.

In this method, cold sheet titanium blanks are placed between cast iron dies heated by electrical resistance units to 500°-600°C. The dies are closed far enough to clamp the sheet stock securely and are held for 3-4 min. in this position. The dies are then closed completely and held for another 3-4 min. The result, when the dies are opened, is a formed part within drawing tolerances and generally sufficiently free of residual stresses to preclude stress relieving. The savings in time, fixture costs, furnace capacity, and power or fuel requirements are obvious.

Recently, success in forming titanium has encouraged the fabrication of larger parts than previously attempted. Large hemispheres and elliptical-shaped domes, up to 36 in. in diameter, have been spun. Special tooling and equipment for spinning titanium hemispheres up to 26 in. in diameter have been designed and built. Spherical segments and hemispheres up to 4 ft. in diameter have been deep drawn.

High-strength titanium alloys are generally more difficult to form than competitive materials in aircraft design. The major emphasis at present is on development of forming techniques for the high-strength sheet alloys. The aim in this case will be to form the sheet in the soft, solution-treated condition, and age to high strength after forming.

Machining and Grinding

Titanium is being machined successfully by those who are aware of its machining characteristics and utilize the required techniques. A study at Boeing Airplane Company of profile-milling-machine requirements for runs of specific airframe parts illustrates the point. The study revealed that Ti-6 Al-4 V alloy, in either the annealed or heat-treated condition, required 1·5 more profile-milling machines than did 7075-T6 aluminium. This ratio, however, was less than that for 4340 steel, a high-strength alloy steel. This steel, in both the annealed and heat-treated conditions, required a machine ratio of 1·9 : 1 over the aluminium alloy for the identical operation.

Welding

Fusion welding, resistance welding and flash welding are now established practices for fabrication of titanium assemblies. Titanium can be fusion welded by both the consumable- and non-consumable-electrode inert-gas-shielded arc processes. Welding may be done in the open by using trailing gas shields and protecting the back of the weld by using close fitting back up bars or inert gas shielding. More complicated parts must be welded in inert-gas-filled welding chambers. Fusion welding has been used to fabricate components for production model turbojet engines and is being used by one company to splice Ti-5 Al-2·5 Sn alloy sheet to obtain sheets larger than the standard available sizes. An interesting recent development, which may be important in sandwich panel development, is the fusion butt welding of thin (0·008 in.) titanium sheet. Some promising work has also been done to develop welded Ti-6 Al-4 V pressure vessels.

Resistance spot and seam welding of titanium and titanium alloys is less of a problem than fusion welding, as it is not necessary to shield the weld area. Components of unalloyed titanium, Ti-5 Al-2·5 Sn, Ti-8 Mn, and Ti-6 Al-4 V, spot and seam welded by conventional processes, are used in production aircraft. Some typical applications are: (1) spot and seam welded unalloyed titanium in the tail section of the F-100 aircraft; (2) spot and seam welded unalloyed titanium, Ti-5 Al-2·5 Sn, and Ti-6 Al-4 V for the engine shroud of the Convair F-102; and (3) spot welded Ti-8 Mn in the tail section of the F 8U Navy jet Crusader.

Flash welding techniques have been used successfully to join a variety of materials, including Ti-4 Al-4 Mn, Ti-3 Al-5 Cr, Ti-6 Al-4 V, Ti-5 Al-2·5 Sn, and Ti-3 Mn-1·5 Al. Although it has been used primarily for fabrication of titanium alloy rings and flanges for engine applications, flash welding offers a promising method of producing large

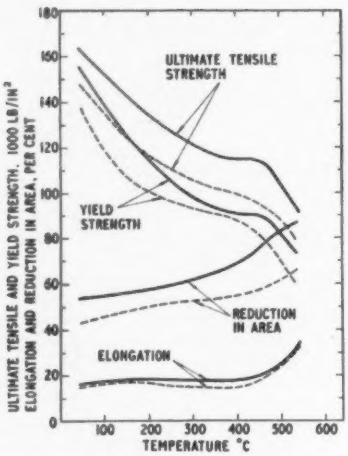


Fig. 3—Elevated temperature properties of heat-treated Ti-6 Al-4 V alloy compared with mill-annealed properties for the same alloy

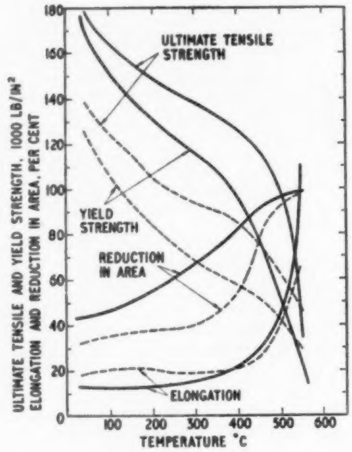


Fig. 4—Elevated temperature properties of heat-treated Ti-2 Fe-2 Cr-2 Mo alloy compared with mill-annealed properties for the same alloy

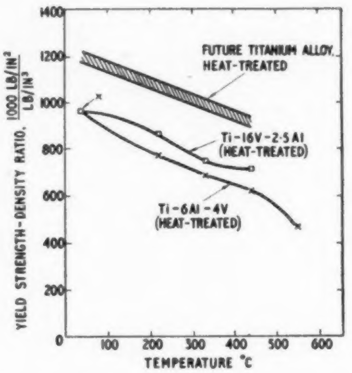


Fig. 5—Comparison of yield-strength-density ratio, as a function of temperature, of two sheet coiling programme alloys and of possible future heat-treatable titanium alloys

complicated components from relatively simply shaped forgings or rolled parts. If flash welding conditions are properly controlled, the molten metal is forced out of the joint during the upsetting operation. Thus, there is little chance that the weld will be contaminated, and inert gas shielding is generally not required. Another distinct advantage is that flash welding can be used to join alpha-beta type alloys which cannot be satisfactorily fusion welded. Flash welded joints generally exhibit mechanical properties approximating those of the base metal, as indicated in Table IV.

Heat-Treatment

Some major advances have been made during recent months in the production heat-treatment of titanium alloys. Airframe structural parts (forgings and machinings), in addition to titanium aircraft fasteners, are now being heat-treated on a production basis to achieve design strength. Sufficient data have been accumulated on the heat-treatment response of the alpha-beta alloys to permit the sale of some titanium mill products on the basis of guaranteed minimum heat-treated properties. An indication of the heat-treatment response of two commercial alloys appears in Figs. 3 and 4.

Heat-treatment of titanium alloy sheet is a challenging development. It must occur for titanium to achieve its full promise in supersonic aircraft and missiles. The co-ordinated Department of Defense sheet rolling programme—in which the three Military Services, three titanium producers, about a score of aircraft companies and private organizations, and the Titanium Metallurgical Laboratory at Battelle (now Defense Metals Information Center) are co-operating—is dedicated to the quick development of the required alloys and the manufacturing procedures for their utilization. These efforts, plus the efforts already mentioned on current commercial alloys, have progressed to the point where it is possible for titanium fabricators to set up tentative production procedures for making high-strength heat-treated parts of titanium sheet.

Alloy Development

At least five new titanium alloys have entered pilot production. Also, the potentials of several older compositions in new forms have been explored. Current titanium-alloy developments are based primarily on military aircraft and missile needs. Thus, emphasis is on increased strength, on improved availability of shapes and forms, and on weldability. A transition from annealed alloys (low strength) to heat-treated alloys (high strength) must soon take place to meet the needs of supersonic flight.

Some typical properties of alloys now in advanced development are given in Table V. With the advent of these (or other) heat-treated alloys, heat-treatment and fabrication procedures must be compatible. Alloys should be capable of fabrication in a soft condition and then heat-treated to the desired strength level. The alloys in Table V are aimed at that requirement.

In Fig. 5, the success experienced in the early stages of the co-ordinated sheet rolling programme is again indicated. Also shown is what is believed a conservative estimate of what may be achieved, in 5 to 10 years, in developing even higher strength commercial alloys if present research

TABLE IV—COMPARISON OF LONGITUDINAL MECHANICAL PROPERTIES OF FLASH WELDED TITANIUM ALLOY WITH PROPERTIES OF PARENT METAL

Material	Ultimate Tensile Strength, lb/in²	Tensile Elongation, per cent in 2 in.	180° Bend Radius	Endurance Limit lb/in²
Ti-4 Al-4 Mn				
¼-in. plate parent metal flash	133,000	15	2·3t	70,000
welded	133,000	11	2·5t	70,000
¾-in. plate parent metal flash	141,000	22*	2·4t	83,000
welded	138,000	19*	3·0t	—
Ti-3 Al-5 Cr				
¼-in. plate parent metal flash	142,500	15	2·4t	84,000
welded	142,500	12	2·4t	70,000
Ti-6 Al-4 V				
½-in. plate parent metal flash	137,000	16*	2·0t	—
welded	135,000	13*	2·5t	—
Ti-5 Al-2·5 Sn				
0·135-in. sheet parent metal	130,000	14	2·5t	—
flash welded	127,000	11	4·0t	—

**In* 1 *inch.*

TABLE V—TYPICAL TENSILE PROPERTIES OF TITANIUM SHEET ALLOYS NOW IN COMMERCIAL DEVELOPMENT

Alloy	Mechanical Properties					
	Room Temperature			430°C.		
	Ultimate Tensile Strength, 1000 lb/in²	Yield Tensile Strength, 1000 lb/in²	Elongation, per cent	Ultimate Tensile Strength, 1000 lb/in.²	Yield Tensile Strength, 1000 lb/in²	Elongation, per cent
DOD Target Properties*	180	160	10	130	105	15
DOD Sheet Rolling Programme Alloys						
Ti-6 Al-4 V	170	155	10	115	100	10
Ti-16 V-2·5 Al	170	160	5	130	120	7
Ti-4 Al-3 Mo-1 V	170	150	10	100	80	15
Higher-Strength Alloys					320°C	
Ti-13 V-11 Cr-4 Al	200	180	5–8	142	125	6
	240	220	2–4	—	—	—
Ti-1 Al-8 V-5 Fe	205	193	6	153	130	7

Alloy	Hours	Creep Strain, per cent	Stress for Indicated Creep Strain, 1000 lb/in²	
			430°C.	540°C.
Creep-Resistant Alloys				
Ti-8 Al-2 Cb-1 Ta	160	0·2	65,000	<15,000
Ti-8 Al-1 Mo-1 V	150	0·1	—	30,000
Ti-5 Al-12 Zr†	500	0·1-0·2	65,000	15,000

**Slightly lower targets apply to Ti-6 Al-4 V alloy.* †*At present bar alloy only.*

programmes are followed through to successful conclusion. In this figure, strength is represented on a yield strength-density index basis

$$\frac{\text{tensile yield strength, lb/in}^2}{\text{density, lb/in}^3}$$

Tensile properties are only one of the criteria for developing new alloys. Alloy selection must be based on intended use and on fabricability. Advanced alpha alloys are being developed that have usable creep strength above 430°C. with good weldability. The Ti-8 Al-2 Cb-1 Ta and Ti-8 Al-1 Mo-1 V alloys are two of several now being worked on. Heat-treatable and non-heat-treatable beta alloys that are weldable are also being developed. Outstanding in the heat-treatable beta category is the Ti-13 V-11 Cr-4 Al composition. Tensile strength of experimental heats of this alloy have been reported in the range of 110-125 tons/in².

References

1 J. J. Russ; "Present Limitations and Future Possibilities in Titanium Forgings," A.S.M. Titanium Conference, Los Angeles, California, 1957, March 25-29.

2 W. A. Mayo and G. J. Matey; "Blanking and Forming Titanium," A.S.M. Titanium Conference, 1957, March 25-29.

Machining in Barrels—*continued from page* 57

influenced by the hydrostatic pressure of the mass. The usually accepted theory, however, postulates that the action is virtually confined to the top layers of the mass, through which components are continuously sliding in a correctly designed and loaded barrel, Fig. 2. In the Almco-Supersheen "Advanced" process, for example, 90 per cent of the action in an octagonal barrel, 30 in. in dia, rotating at 20 r.p.m., is believed to occur in a sliding layer less than 3 in. deep. It is generally agreed that a relatively large diameter and well-filled barrel operates more satisfactorily than a small and/or lightly loaded one, but this is explicable by the greater pressures in the first theory, and by the longer slide in the second.

By ringing the changes on the above variables, a very wide choice of conditions for a given operation are made available; some simplification is possible, however, since normal loading for a horizontal unit is 60 to 75 per cent full, while four different water levels are generally accepted[2]—low, i.e. up to 2 in.; medium, within 2 in. of the top of the mass; level—with mass, that is; and high, 2 in. above mass level. Again, the speed of rotation is limited by the tendency for the mass to be drawn up the side of the barrel sufficiently far for it to be thrown instead of sliding. The larger the diameter, the lower the limiting speed; about 70 r.p.m. is the limit, and most operations are conducted at 20-30 r.p.m. Thus, in the Almco Supersheen process the essential variables are reduced to 135—a large but none the less manageable aggregate.

The scope of modern barrelling has gained generous publicity, but it is none the less true that some incredibly awkward shapes are successfully treated, while remarkably high non-directional surface finishes, comparable with lapped or honed surfaces, are possible on selected materials and shapes; thus, a fuel injection pump component is precision barrelled by a submerged barrelling process to a 2μ finish and to an accuracy better than 0·1 mil, at 1 per cent of the cost of conventional finishing (Fig. 3). There are, however, well-defined limitations, the principal one being the completely non-selective character of the technique. Whereas, therefore, the manual operator can make allowances for isolated surface imperfections it will prove necessary either to remove these manually prior to barrelling, or else greatly to prolong the operation for their complete removal. Again, since projections inevitably become subjected to preferential wear, all corners and edges will become radiused; similarly, only rarely will a surface escape treatment, and the preservation of a certain finish on a given area of an article—with the exception of threaded portions—can generally be regarded as largely impracticable. Two further limitations are generally accepted: one is that a finish equal to that obtainable by hand finishing cannot be secured on components weighing more than about 4 oz.; the other is that, with recessed work, if the depth of the recess is more than a half of its diameter it is uneconomical to barrel finish the recess.

References

1 C. J. Kellard; *Electroplating*, 1955, March and April.

2 W. Biebel; *Plating*, 1958, January.

(To be continued)

Industrial News

Home and Overseas

Casting Alloys

An announcement has been made by **Henry Wiggin and Company Ltd.** that Nimocast 713C nickel-chromium casting alloy has been added to the range of Nimocast alloys and is now available in this country. Nimocast 713C is the Wiggin-made equivalent of Inconel 713C, an investment casting alloy for high-temperature service developed in the research laboratories of The International Nickel Company Inc., and already specified for the turbine rotor blading of a number of U.S. gas-turbine aero-engines.

This alloy is one of a number of complex high-nickel casting alloys developed in recent years for high-temperature turbine blading. It is said to combine outstanding strength with excellent resistance to thermal fatigue at temperatures up to 980°C. In the U.S.A., where cast rotor blades are considered acceptable for production engines, and are, in fact, used in substantial numbers, this alloy is now well established and has won a reputation for reliability under arduous service conditions.

Nimocast 713C is stated to be readily castable and develops its best properties when cast in vacuum. Alternatively, it can be cast under a protective atmosphere such as argon. A heat-treatment of 2 hr. at 1,170°C., followed by air cooling, is beneficial but not essential unless the maximum mechanical properties are required.

Light Alloy Van Body

An interesting new aluminium alloy van body of simple construction that makes it suitable for marketing in kit form and for assembly by unskilled labour has been designed by **Northern Aluminium Company Ltd.** The prototype body, which has been built by Willowbrook Limited, is mounted on an Austin 5-ton normal control diesel chassis.

The body is made up of Noral B51SWP aluminium alloy sheets riveted to extruded sections of the same alloy. This method of construction gives great strength and resistance to denting. A full-length top-hat section rubbing rail (also in Noral B51SWP) gives protection to the body sills. The body weighs only 10 cwt. complete with heavy-duty extruded Noral B51SWP floor planks and full-height double doors.

Aluminium flooring or lining could be supplied with the kit if required, while a variety of aluminium rear door closure arrangements have also been designed. This new method of supplying packaged body kits should be of great assistance to overseas body-builders, for it enables them to obtain pre-engineered body shells that can easily be assembled by local labour and fitted out to serve local conditions, operators' requirements and types of load.

New Appointments

Service to their customers is the keynote of a new appointment announced by the **Electric Resistance Furnace Co. Ltd.** Mr. H. J. Tucker, the company's Southern Area sales manager, now becomes service manager. He will continue to operate from the company's head office at Weybridge.

Mr. C. A. McNeill has joined the technical sales staff of the company at their Midlands area office in Birmingham, and Mr. M. J. Parsons, who has been for many years with Edwards High Vacuum Ltd., has joined the Efco sales organization at Weybridge, where he will specialize in vacuum heat-treatment processes and equipment.

Screw Thread Standards

As the engineering world seems to be so bedevilled by the multiplicity of screw thread standards, **W. H. A. Robertson and Co. Ltd.** decided to collate, in one volume, the screw thread standards of the world and to give them a common denominator of comparison.

This has resulted in the publication of a 44-page booklet in which over 2,000 standards are listed from the 33 countries which have published their own national standards for screw threads. In addition, no less than 108 screw thread forms are illustrated, together with self-tapping screws.

It is interesting to note that, of the 33 countries covered in this "guide," 27 have standards for British Whitworth form of thread, 23 have standards for metric form of thread, and six have standards for American form of thread. As can be imagined, a great deal of research and expense has been involved in the production of this book and the company is charging the sum of ten shillings for a work which is of the utmost value to the engineer.

Bronze and Brass Founders

A meeting of members of the **Association of Bronze and Brass Founders** in the Midlands area is to be held at the Victoria Hotel, Wolverhampton, on Wednesday, September 9, commencing at 11.45 a.m., when current association business and other matters of interest may be discussed.

Following luncheon at 1 p.m., there will be a talk by Mr. W. H. Davies, at which practical advice will be given on installing and operating the system advocated in the association's publication, "Costing a Casting."

Corrosion Prevention

It is announced that **R. Cruickshank Ltd.,** of Birmingham, have concluded an agreement with Allied Research Products Inc. of Baltimore, U.S.A., under which the British company is granted exclusive licence for the manufacture and sale in the United Kingdom of a wide range of Iridite products for use in metal corrosion prevention processes, also for the sale of these products in certain countries overseas.

By agreement with the American company, license to use the Iridite trade mark is also granted.

Merchants' Works Rebuilt

Originally started in 1927 and formed into a limited company in 1953, the business of **Geo. E. Tranter Ltd.** has made rapid progress, handling all classes of non-ferrous scrap materials and residues, and supplying foundries with graded scrap suitable to their requirements.

In order to provide additional warehouse and office accommodation, and also to meet the development of the district as laid down by the Planning Authority, the works at Adams Street, Birmingham, 7, have recently been rebuilt.

The increased warehouse accommodation provides excellent messroom facilities for the works staff, and up-to-date washing facilities have also been provided. One of the features of the planning of the new works is the incorporation of mechanical handling equipment, which enables a much quicker turn round of vehicles.

The frontage of the rebuilt warehouse and works of Geo. E. Tranter Ltd.

I.C.I. at Farnborough

At the forthcoming S.B.A.C. Exhibition, to be held at Farnborough next month, four stands will be occupied by divisions of **Imperial Chemical Industries Limited.** On Stand 57, the Metals Division will be featuring aircraft components made from the new titanium alloys mentioned in this journal last week.

On Stand 87, Marston Excelsior Ltd. will show a range of heat exchangers in titanium, stainless steel and light alloy, cabin coolers, oil coolers, fuel heaters and light alloy cooling devices for electronic

equipment. The Paints Division will occupy Stand 80, and the Plastics Division Stand 86.

A Paris Meeting

Advance notice is given of a Colloquium on Sheet Metal Forming, with special emphasis on methods of testing, organized jointly by the Société Française de Métallurgie and the International Deep Drawing Research Group, to be held in Paris from May 23 to 25 next year.

London Address

It is learned from **Compoflex Company Ltd.** that they have now opened a London warehouse at Angel House, Pentonville Road, London, N.1, where stocks of their products will be held. Included in these stocks will be a range of Pirelli long length moulded rubber hoses, following an arrangement with the Pirelli Company of Milan whereby Compoflex will in future undertake the marketing in the U.K. and Northern Ireland of certain long length hoses made by the Italian company.

New Shot Blast Helmet

A wider angle of vision and greater comfort are among the outstanding features of the new "Black Knight" shot blast helmet recently introduced by the **R.F.D. Company.** The helmet is said to be unique in that it can be kept in permanent commission. All parts are replaceable and spares can be kept in hand, so that it need never be returned to the manufacturers for maintenance or servicing. Since all parts are washable, a high standard of hygiene can be maintained.

The specially reinforced shell is moulded in glass fibre and covered with a tight fitting Latex envelope, made in two window sizes. A soft, adjustable polythene headband, chinstrap and wash leather sweat band provide extra comfort. The air inlet connection for $\frac{3}{8}$ in. bore supply hose is at the back of the helmet, and air is channelled downwards over the window to prevent misting.

Head fitting is designed in such a way that whenever the head is turned the window moves with it, ensuring that the operator is always looking through the window and suffers no loss of vision.

Japanese Aluminium Company

According to the news from Osaka, the Sumitomo Metal Industry Company is stated to be establishing a new company specializing in the production of aluminium rolled products. The new company—to be called the Sumitomo Light Metal Industry—would introduce new techniques from Aluminium Limited of Canada.

The Sumitomo project was envisaged to meet competition from the newly-established Furkawa Aluminium Company, which is tied up with the Aluminum Company of America (Alcoa), and from the Kobe Steel Company, another leading aluminium rolling mill, which is also planning to make a technical tie-up with the Aluminum Company of Canada (Alcan).

A Merger

We are informed that **Inspection Services Ltd.** and **R. F. Fraser-Smith** have decided to merge their interests. Enquiries and orders for non-destructive testing equipment, including radioactive isotope containers, and a new portable magnetic crack detector, weight 45 lb., giving an output of 750 amperes, with a built-in changeover switch for operation on 100/120 or 200/250 V A.C. single-phase supply, should be addressed to Inspection Services Ltd., Oldfields Trading Estate, Sutton By-Pass, Sutton, Surrey.

Overseas Contract

News from **Marco Conveyor and Engineering Co. Ltd.** is to the effect that, in conjunction with the **Constructional Engineering Co. Ltd.,** they have obtained an order from Yugoslavia for the supply of a complete mechanized foundry for the production of tractor engines.

The order was obtained in the face of competition from both home and abroad. The whole of the equipment will be designed in this country, but some portions of the steelwork will be fabricated in Yugoslavia. The value of the equipment to be manufactured in this country is stated to be £73,000.

Induction Heating

Although the Pye Process Heating Division of **Pye Limited** have been manufacturing R.G. generators for the wood trade during the last 15 years, they have now started making them for use in the metal trades. The first induction heater in this new range is the R.F.1, which gives a continuous output of 3 kW at 2 Mc/s and has been designed for bench operation, the overall dimensions being 26½ in. high, 22 in. wide and 25¼ in. deep.

The unit is housed in an aluminium cubicle and is finished in green-grey Hammertone enamel with safety switches on the removable sides. The equipment is self-contained, with its own automatic resetting process timer and an overload relay to protect the oscillator valve. Provision is made for remote control and a pulse is available at the end of the heating cycle to initiate a quenching, or any other operation required.

The oscillator valve and coil are water-cooled, using 1·5 gal/min. with a flow switch in the supply which will switch off the equipment should the water fail, so protecting the valve from overheating. The equipment is designed to be operated from a 3-phase supply, 360-460 V at 50 cycles, with a full load consumption of 6·1 kW.

Dry Lubrication

Based on PTFE (polytetrafluoroethylene), some recently developed dry bearing materials produced by **Glacier Metal Co. Ltd**. will be displayed under test on the D.S.I.R. stand at the Scottish Industries Exhibition next month.

In 1954 a pilot plant was set up at Kilmarnock, where the first PTFE dry bearing material was commercially produced in the following year. It was called "DP," in keeping with the company's simple code system, and was used for bearings and thrust washers. It had certain limitations and further research led to an improved form of the material with even better bearing properties. Known as "DU," the improved material is also available in strip form and will perform as a bearing material carrying heavy loads and operating at high speeds without the provision of external lubricants.

As "DU" cannot be machined, the company has developed a dry bearing material, containing a mixture of PTFE, especially suitable for the manufacture of bearings by the process of machining. It is called "Glacier DQ," and is claimed to have outstanding wear resistance properties.

Finally, the range of available materials was completed by the addition of two surface treatments. They are for application to ferrous and some other metals.

Furnace Sales

With effect from September 1, 1959, **Birlec Limited** is to establish a Midland area sales office, with Mr. H. J. Podmore as manager. The new office will be situated at the company's main premises in Tyburn Road, Birmingham, 24.

Mr. Podmore joined Birlec in April, 1955, as sales manager, Dryer and Gas Plant Division.

Safety Campaign

It has been announced by the Industrial Safety Division of the **Royal Society for the Prevention of Accidents** that the national safety campaign, planned for the week beginning September 28, has now been postponed until the week beginning November 23. The Society will issue a detailed announcement about the campaign at the end of September.

Scottish Acquisition

In order better to meet competition from overseas, **G. and J. Weir Holdings Ltd.** have acquired Lobnitz and Co. Ltd., shipbuilders and engineers, of Renfrew. The Lobnitz yard adjoins William Simons and Co. Ltd., which is also controlled by Weir. Both yards specialize in dredger building, and have modernized extensively. They produce factory ships, tugs, floating cranes and similar working craft. The Lobnitz yard was one of the first to swing to all-welded construction, and both yards have built up their premises and plant on modern lines. Unified control will give Weir and the two yards a much improved position in the dredger field against foreign competition. Lobnitz will also provide valuable welding and heavy machining capacity for the Weir group as a whole.

Indian Aluminium Plant

Plans to establish an integrated aluminium producing industry in India have been completed by Kaiser Aluminium Corporation and the Birla interests in India.

Kaiser Aluminium and Birla have organized the Hindustan Aluminium Corporation Limited as a joint venture to construct and operate an aluminium production plant at Rihand, in Uttar Pradesh province in central India, together with related bauxite and alumina facilities.

The plant, to have an annual capacity of 20,000 metric tons of primary metal, is expected to begin operations in 1962.

Power for the alumina refining and aluminium production plants will be obtained from the Rihand Dam, and bauxite supplies from the nearby Amarkantak area.

Forthcoming Meetings

September 1—Institute of Metal Finishing. Midland Branch. James Watt Memorial Institute, Great Charles Street, Birmingham 3. Chairman's Address. J. Beddows. 6.30 p.m.

September 3—Institute of Metal Finishing. North-West Branch. Engineers' Club, Albert Square, Manchester "Hull Cell" (with particular advantage to the Plating Shop Foreman). R. Winstanley. 7.30 p.m.

Metal Market News

THE market situation last week was dominated by events in the United States, where, by the time trading in Whittington Avenue came to an end on Friday afternoon, virtually the whole of the copper producing industry was strikebound. To make matters worse there was a threat to the refining of Chilean blister through the likelihood of a shut-down at the plant of American Smelting and Refining Co. This would interfere with shipments of copper to Europe, and if the strike in America drags on for a considerable time the situation could become serious. One must presume that any question of output curtailment is shelved for the present since it would obviously be ridiculous to reduce production at a time when something like 40 per cent of the world's copper supplies are not available owing to the cessation of operations in the States. As we write there is some talk of the trouble in the steel strike being resolved within a matter of days and if this should fortunately turn out to be true then the way for an early settlement of the copper strike would certainly be made easier. On the question of how long consumers in the United States can carry on without running into a condition of shortage opinions differ, but at any rate they ought to have secured cover sufficient to last them for some weeks. Probably there has never been a shut-down in the history of copper so well advertised in advance as the present one. In a sense, the standard market last week proved to be something of a gambler's paradise for the close was well above the lowest and at the same time under the best. Stocks were down 245 tons to 15,038 tons, but Monday's prices eased on the news that Calumet and Hecla had negotiated a wages settlement. In the afternoon, however, the cash price declined by £8 on the report that workers at Anaconda's Butte mine had offered to continue working on the understanding that they should receive in due course the same rate of pay as that negotiated with the workers at other properties. This was fairly promptly turned down by the employers, and copper recovered on Tuesday to £234. Steady conditions prevailed thereafter till Friday when the trend was again downwards, with three months at £231 15s. 0d. at midday. The Kerb was 10s. lower. In the afternoon the volume of business was restricted, but the downward trend continued. Finally, after a turnover of 10,650 tons cash closed £4 15s. 0d. lower at £233 10s. 0d., while three months was also £4 15s. 0d. down at £231 15s. 0d.

Trading in tin was patchy and rather quiet, the close after a turnover of 510 tons being £793 for cash, £1 down on balance, and £793 three months, in which position there was no change. In mid-week August zinc stood at £87, but the close was £1 below this. November closed 15s. down at £84 10s. 0d.

Some 5,350 tons changed hands during the week. In that period lead fluctuated within narrow limits to close 7s. 6d. down for August and 2s. 6d. lower for November at £74 7s. 6d. The turnover was 9,000 tons. Both lead and zinc have certainly done well recently but of the two metals zinc seems to be the more favoured for further appreciation. Indeed, the price is talked up to £90 and even higher. While it is true that the ending of the steel strike ought to bring an increased demand, the existence of import quotas in the United States makes it obvious that this increase will not benefit the position here.

Birmingham

Consumption of non-ferrous metal in the Birmingham area remains fairly steady. The general trend of trade is upwards, and it is significant that there are more vacancies for skilled and semi-skilled workers than has been the case for some months. Producers of components for the motor trade are sending supplies regularly to the car assembly shops, and the outlook for this class of business is bright. After a dull spell, more business has come to makers of machine tools, but there is still spare capacity in this direction. Some improvement is noted in building and shopfitting work. Output in mechanical and electrical engineering works is greater than it was a year ago.

It is believed that some of the spare output in the iron and steel industry will be brought into commission before the end of the year to meet increasing demands for raw material. Deliveries to nearly all consuming industries have risen gradually. The exceptions have been the railways, the mining industry and shipbuilding. With a big demand from the motor trade, sheet and strip mills remain very active, and there has been considerable improvement in the iron foundries as compared with the position at the beginning of the year when unemployment reached serious proportions. Imports of steel are at a low ebb, as supplies are available promptly from local works.

New York

At the week-end, copper futures were steadier in the nearbys but the more distant positions were losing their earlier gain. Dealings were fairly active. The Mine Mill Union extended the contract with the American Brass Company, a fabricating subsidiary of Anaconda. Dealers reported active consumer interest in foreign copper or guaranteed delivery domestic copper for September at 33 to 33¼ cents per lb. Tin was quiet and steadier. Lead and zinc were fairly active. In late trading, tin was barely steady but quiet. The Mine Mill Workers' Union hinted at an extension of the strike deadline at the American Metal Climax's subsidiary, the U.S. Metals Company.

A Bill, the Supplemental Appropriations Act, giving the Office of Civil and Defense Mobilization (O.C.D.M.) 108 million dollars to meet cash requirements of the Defense Production Act (D.P.A.) stockpile inventory for operations in the fiscal year 1960, which began last July 1, has now moved closer to becoming law. It appropriates 977,345,608 dollars in new funds to cover operating expenses of a number of Federal Government departments, including O.C.D.M.

The O.C.D.M. will use part of its new funds to buy metals and minerals for the D.P.A. inventory. On March 31 this year, the D.P.A. inventory held 657,713 short tons of aluminium, 135,780 short tons of copper, 81,300,991 lb. of nickel, 79,814,281 lb. of tungsten and 2,384,463 long dry tons of metallurgical manganese.

Paris

The Ste Penarroya has decided to expand zinc production and has announced the building of a new foundry at Noyelles-Godault which will come into operation in 1961. The new plant will be one of the most efficient and modern of its kind, and will have a capacity of 35,000 tons per year, which is more than double any plant now in existence belonging to the company. It will produce thermic zinc, which is in demand in France. It will also operate with mixed minerals such as zinc and lead.

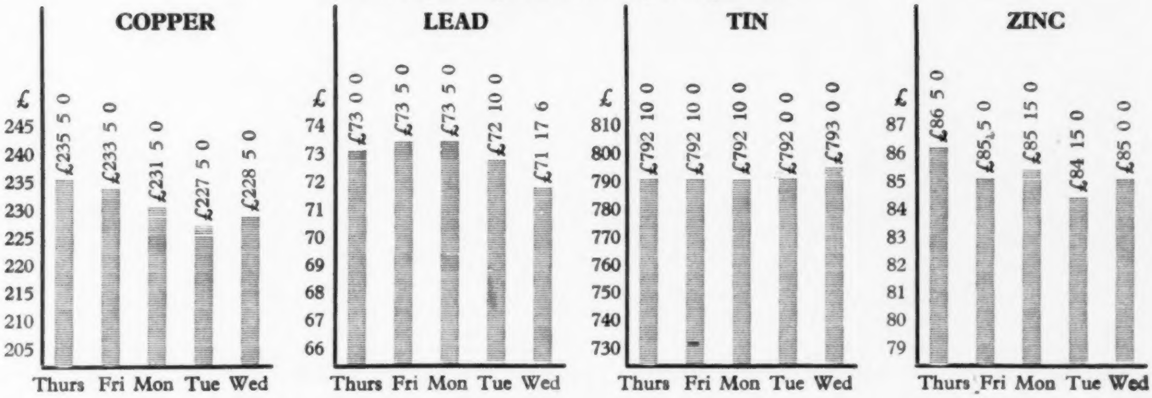
No date has yet been fixed for the French atom bomb test, and it will take a long time yet. One reason is that the plant at Marcoule which produced plutonium from uranium is not producing sufficient, and the new pile, G.3, which came into operation in July, will not actually start producing plutonium for many months. G.3 is still in the experimental stage, and it is too early to write what its output is likely to be. Its electric power is given as over 30 megawatts. It is estimated that when G.3 is in operation, G.1, G.2 and G.3 will be producing about 100 kg. of plutonium per year.

Duralumin reports that production is up in 1959 by about 10 per cent. Over the past three years production has increased at a rate of 10 per cent per year, thanks to extensive investments in new installations. A new plant at Sainte Genevieve will soon come into production. Exports are rising, and it is estimated that gross figures will show increased business around 25 per cent.

Non-Ferrous Metal Prices

London Metal Exchange

Thursday 20 August to Wednesday 26 August 1959



Primary Metals

All prices quoted are those available at 2 p.m. 26/8/59

		£	s.	d.
Aluminium Ingots	ton	180	0	0
Antimony 99·6%	„	197	0	0
Antimony Metal 99%	„	190	0	0
Antimony Oxide	„	180	0	0
Antimony Sulphide Lump	„	190	0	0
Antimony Sulphide Black Powder	„	205	0	0
Arsenic	„	400	0	0
Bismuth 99·95%	lb.		16	0
Cadmium 99·9%	„		9	0
Calcium	„	2	0	0
Cerium 99%	„	16	0	0
Chromium	„		6	11
Cobalt	„		14	0
Columbite per unit			—	
Copper H.C. Electro	ton	228	5	0
Fire Refined 99·70%	„	227	0	0
Fire Refined 99·50%	„	226	0	0
Copper Sulphate	ton	76	0	0
Germanium	grm.		—	
Gold	oz.	12	10	0½
Indium	„		10	0
Iridium	„	24	0	0
Lanthanum	grm.		15	0
Lead English	ton	71	17	6
Magnesium Ingots	lb.		2	3
Notched Bar	„		2	9½
Powder Grade 4	„		6	1
Alloy Ingot, A8 or AZ91	„		2	4
Manganese Metal	ton	245	0	0
Mercury	flask	72	0	0
Molybdenum	lb.	1	10	0
Nickel	ton	600	0	0
F. Shot	lb.		5	5
F. Ingot	„		5	6
Osmium	oz.		nom.	
Osmiridium	„		nom.	
Palladium	oz.	7	5	0
Platinum	„	28	10	0
Rhodium	„	41	0	0
Ruthenium	„	18	0	0
Selenium	lb.		nom.	
Silicon 98%	ton		nom.	
Silver Spot Bars	oz.		6	6
Tellurium	lb.		15	0
Tin	ton	793	0	0
***Zinc**				
Electrolytic	ton		—	
Min 99·99%	„		—	
Virgin Min 98%	„	84	6	3
Dust 95/97%	„	114	0	0
Dust 98/99%	„	120	0	0
Granulated 99+%	„	109	6	3
Granulated 99·99+%	„	122	18	9

* *Duty and Carriage to customers' works for buyers' account.*

Foreign Quotations

Latest available quotations for non-ferrous metals with approximate sterling equivalents based on current exchange rates

	Belgium fr/kg	≏£/ton	Canada c/lb	≏£/ton	France fr/kg	≏£/ton	Italy lire/kg	≏£/ton	Switzerland fr/kg	≏£/ton	United States c/lb	≏£/ton
Aluminium			22.50	185 17 6	224	165 0	375	221 5	2.50	212 10	26.80	214 10
Antimony 99.0					220	163 0	445	262 10			29.00	232 0
Cadmium					1.300	975 0					120.00	960 0
Copper												
Crude												
Wire bars 99.9							445	262 12 6				
Electrolytic	32.50	239 5 0	29.00	238 12 6	326	244 12 6			2.75	233 17 6	30.00	240 0
Lead			10.50	86 15	107	81 2 6	163	96 2 6	.88	74 17 6	12.00	96 0
Magnesium												
Nickel			70.00	578 5	900	675 0	1,200	708 0	7.50	637 10	74.00	592 0
Tin	112.00	831 17 6			1,123	842 5	1,500	885 0	9.70	824 12 6	102.50	820 0
Zinc												
Prime western			11.50	95 0 0							11.00	88 0
High grade99.95			12.10	100 0 0								
High grade99.99			12.50	103 2 6								
Thermic					126.00	95 0						
Electrolytic					134.00	100 10	184	108 12 6	1.05	89 2 6	12.25	98 0

Non-Ferrous Metal Prices (continued)

Ingot Metals

All prices quoted are those available at 2 p.m. 26/8/59

Aluminium Alloy (Virgin)

		£	s.	d.
B.S. 1490 L.M.5	ton	210	0	0
B.S. 1490 L.M.6	„	202	0	0
B.S. 1490 L.M.7	„	216	0	0
B.S. 1490 L.M.8	„	203	0	0
B.S. 1490 L.M.9	„	203	0	0
B.S. 1490 L.M.10....	„	221	0	0
B.S. 1490 L.M.11....	„	215	0	0
B.S. 1490 L.M.12....	„	223	0	0
B.S. 1490 L.M.13....	„	216	0	0
B.S. 1490 L.M.14....	„	224	0	0
B.S. 1490 L.M.15....	„	210	0	0
B.S. 1490 L.M.16....	„	206	0	0
B.S. 1490 L.M.18....	„	203	0	0
B.S. 1490 L.M.22....	„	210	0	0

†Aluminium Alloys (Secondary)

B.S. 1490 L.M.1	ton	153	0	0
B.S. 1490 L.M.2	„	163	0	0
B.S. 1490 L.M.4	„	178	0	0
B.S. 1490 L.M.6	„	189	0	0

***Aluminium Bronze**

BSS 1400 AB.1......	ton	227	0	0
BSS 1400 AB.2......	„	236	0	0

***Brass**

		£	s.	d.
BSS 1400-B3 65/35 ..	ton	152	0	0
BSS 249	„	—		
BSS 1400-B6 85/15 ..	„	195	0	0

***Gunmetal**

R.C.H. 3/4% ton	„	—		
(85/5/5/5) LG2	„	188	0	0
(86/7/5/2) LG3	„	199	0	0
(88/10/2/1)	„	236	0	0
(88/10/2/½)	„	249	0	0

***Manganese Bronze**

BSS 1400 HTB1....	„	180	0	0
BSS 1400 HTB2....	„	200	0	0
BSS 1400 HTB3....	„	212	0	0

Nickel Silver

Casting Quality 12%	„	228	0	0
„ „ 16%	„	235	0	0
„ „ 18%	„	248	0	0

***Phosphor Bronze**

B.S.1400 P.B.1.(A.I.D. released)	„	283	0	0
B.S. 1400 L.P.B.1	„	210	0	0

**Average prices for the last week-end.*

Phosphor Copper

		£	s.	d.
10%	ton	253	0	0
15%	„	255	10	0

Phosphor Tin

5%	„	—		

Silicon Bronze

BSS 1400-SB1	„	235	0	0

Solder, soft, BSS 219

Grade C Tinmans....	„	369	15	0
Grade D Plumbers..	„	297	15	0
Grade M	„	405	10	0

Solder, Brazing, BSS 1845

Type 8 (Granulated)	lb.	—		
Type 9 „	„	—		

Zinc Alloys

Mazak III	ton	116	3	9
Mazak V	„	120	3	9
Kayem	„	126	3	9
Kayem II	„	132	3	9
Sodium-Zinc	lb.		2	7

Semi-Fabricated Products

Prices vary according to dimensions and quantities. The following are the basis prices for certain specific products.

Aluminium

Sheet 10 S.W.G.	lb.		2	8½
Sheet 18 S.W.G.	„		2	10½
Sheet 24 S.W.G.	„		3	1½
Strip 10 S.W.G.	„		2	8½
Strip 18 S.W.G.	„		2	9½
Strip 24 S.W.G.	„		2	11
Circles 22 S.W.G.	„		3	2½
Circles 18 S.W.G.	„		3	1½
Circles 12 S.W.G.	„		3	0½
Plate as rolled	„		2	8
Sections	„		3	2
Wire 10 S.W.G.	„		2	11¼
Tubes 1 in. o.d. 16 S.W.G.	„		4	1

Aluminium Alloys

BS1470. HS10W.				
Sheet 10 S.W.G.	„		3	1
Sheet 18 S.W.G.	„		3	3½
Sheet 24 S.W.G.	„		3	11
Strip 10 S.W.G.	„		3	1
Strip 18 S.W.G.	„		3	2½
Strip 24 S.W.G.	„		3	10½
BS1477. HP30M.				
Plate as rolled......	„		2	11
BS1470. HC15WP.				
Sheet 10 S.W.G.	„		3	9½
Sheet 18 S.W.G.	„		4	2
Sheet 24 S.W.G.	„		5	0½
Strip 10 S.W.G.	„		3	10½
Strip 18 S.W.G.	„		4	2
Strip 24 S.W.G.	„		4	9½
BS1477. HPC15WP.				
Plate heat treated..	„		3	6¼
BS1475. HG10W.				
Wire 10 S.W.G.	„		3	10½
BS1471. HT10WP.				
Tubes 1 in. o.d. 16 S.W.G.	„		5	0¼
BS1476. HE10WP.				
Sections	„		3	1¼

Brass

Tubes..............	„		1	10¼
Brazed Tubes........	„		3	0⅜
Drawn Strip Sections	„		—	
Sheet	ton	202	10	0
Strip	„	202	10	0
Extruded Bar........	lb.		2	2¾
Extruded Bar (Pure Metal Basis)	„		—	

Brass

Condenser Plate (Yellow Metal)	ton	193	0	0
Condenser Plate (Naval Brass)	„	204	0	0
Wire	lb.		2	8

Beryllium Copper

Strip	„	1	4	11
Rod................	„	1	1	6
Wire	„	1	4	9

Copper

Tubes	lb.		2	3¾
Sheet	ton	261	5	0
Strip	„	261	5	0
Plain Plates	„		—	
Locomotive Rods	„		—	
H.C. Wire	„		—	

Cupro Nickel

Tubes 70/30	lb.		3	6⅞

Lead

Pipes (London)	ton	111	5	0
Sheet (London)	„	109	0	0
Tellurium Lead	„	£6 extra		

Nickel Silver

Sheet and Strip 7% ..	lb.		3	8½
Wire 10%	„		4	3¼

Phosphor Bronze

Wire	„		4	0⅝

Titanium (1,000 lb. lots)

Billet 4½" to 18" dia...	lb.	54/-	55/-
Rod ¼" to 4" dia.	„	95/-	62/-
Wire ·036" – ·232" dia.	„	167/-	110/-
Strip ·003" to ·048" ..	„	200/-	75/-
Sheet 8'×2'. 20 gauge	„	85/-	
Tube, representative average gauge......	„	300/-	
Extrusions	„	105/-	

Zinc

Sheet	ton	121	15	0
Strip	„	nom.		

Domestic and Foreign

Merchants' average buying prices delivered, per ton, 25/8/59.

Aluminium

	£
New Cuttings	145
Old Rolled	126
Segregated Turnings	99

Brass

Cuttings	155
Rod Ends	145
Heavy Yellow	120
Light	114
Rolled	147
Collected Scrap	117
Turnings	139

Copper

Wire	208
Firebox, cut up	201
Heavy	196
Light	190
Cuttings	208
Turnings	191
Braziery	160

Gunmetal

	£
Gear Wheels	175
Admiralty..................	175
Commercial	159
Turnings	154

Lead

Scrap	63

Nickel

Cuttings	—
Anodes	550

Phosphor Bronze

Scrap	159
Turnings	154

Zinc

Remelted	74
Cuttings	57
Old Zinc	38

Financial News

William Jacks and Co.

Dividend 15 per cent (same), capital distribution 5 per cent (2½ per cent distribution paid last January) and one-for-two scrip issue. Group net profit for 1958 £123,292 (£156,433). Total net assets of £1,682,999 (£1,674,322) include net current assets £1,435,256 (£1,466,937).

Oldham and Son Ltd.

The 1958-59 group net profit, including £5,000 (£15,000) unrequired tax, fell from £236,931 to £171,167. Dividend repeated at 17½ per cent. General reserve receives £22,537 (£72,537), £337,559 (£311,413) is carried forward. Current assets, £1,743,306 (£1,885,029). Current liabilities of £1,202,853 (£1,324,917) include £569,322 (£504,064) due to bankers.

New Companies

The particulars of companies recently registered are quoted from the daily register compiled by Jordan and Sons Limited, Company Registration Agents, Chancery Lane, W.C.2.

Corrosion Consultants Ltd. (630067), 159 Boundary Road, N.22. Registered June 10, 1959. To act as consultants on any subject connected with corrosion and metal finishings, etc. Nominal capital, £100 in £1 shares. Directors: Bernard C. Taylor, Lewis H. Staines and John H. Nicholls.

T. G. and W. Wood Pressings and Forgings Limited (630199), 2 Lombard Street West, West Bromwich. Registered June 11, 1959. Nominal capital, £100 in £1 shares. Directors: Eustace J. Spurway and John W. Dickens.

Thorn Leon Steel & Metal Agencies Limited (630711), 101 Finsbury Pavement, E.C.2. Registered June 18, 1959. Nominal capital, £1,000 in £1 shares. Directors: Rupert W. Leon and Leslie Thorn.

C. and H. Metal Pressings (Bradford) Limited (630722), 13 Stone Street, Bradford. Registered June 18, 1959. Nominal capital, £500 in £1 shares. Directors: Arthur B. Mitchell and Betty L. Pooley.

Interlas Limited (630746), 232 Bromham Road, Bedford. Registered June 19, 1959. To carry on business of dealers in welding plant and accessories and in engineering, machine and other tools, etc. Nominal capital, £3,000 in £1 shares. Directors: Eric L. Courtney and Harmer C. Van Arum.

Cleveland Metals Limited (631903), Zetland Buildings, Longbeck Trading Estate, Marske by the Sea, Redcar. Registered June 23, 1959. Nominal capital, £4,000 in £1 shares. Directors: Noah O. Tucker, Darrell Tucker and Wm. Clare.

G. A. Wainwright and Son Limited (631215), Burgess Street, off Sanvey Gate, Leicester. Registered June 26, 1959. To carry on business of chromium platers, electro platers, etc. Nominal capital, £5,000 in £1 shares. Director: Peter G. Wainwright.

Roland Grosvenor Workman Metal Finishers Limited (631341), 34 Bath Row, Birmingham. Registered June 29, 1959. Nominal capital, £3,000 in £1 shares. Permanent directors: Roland G. Workman, Norris R. Watkins and Bertram Westwood.

Alex. Gill and Co. (Coleshill) Limited (631421), 106 Stechford Road, Birmingham, 24. Registered June 30, 1959. Nominal capital, £10,000 in £1 shares. To carry on business of diecasters and die makers, tool makers, etc. Directors not named.

Cradley Plating Co. Limited (631527), 56-7 Reddal Hill Road, Old Hill, Staffs. Registered June 30, 1959. Nominal capital, £2,000 in £1 shares. Directors: Thomas L. Tibbetts, Alfred E. Howell, John Jones and Cedric J. Jones.

P. and H. Metal Products (Kingston) Limited (631592), Old Castle Wharf, Lower Teddington Road, Hampton Wick, Kingston-on-Thames. Registered July 1, 1959. To take over business of tool makers and general engineers carried on at Kingston-on-Thames by P. A. H. Pryce and A. C. Herbert. Nominal capital, £100 in £1 shares.

G. & M. Partners Limited (631866), 36-42 Staines Road West, Sunbury, Middx. Registered July 3, 1959. To carry on business of industrial finishers, enamellers, cellulose and paint sprayers, etc. Nominal capital, £100 in £1 shares. Directors: Stanley E. Mansfield and Geoffrey P. J. Roberts.

Good Design Limited (632014), 12 Tower Hill, Bristol, 2. Registered July 6, 1959. To carry on business of light industrial metal workers, metal grinders, etc. Nominal capital, £5,000 in £1 shares. Directors: Geo. E. Poeton and Francis A. McAweeny.

Scrap Metal Prices

The figures in brackets give the English equivalents in £1 per ton:—

West Germany (D-marks per 100 kilos):

Used copper wire ..	(£210.5.0)	240
Heavy copper	(£201.10.0)	230
Light copper	(£175.5.0)	200
Heavy brass	(£118.5.0)	135
Light brass	(£96.12.6)	105
Soft lead scrap	(£56.0.0)	64
Zinc scrap	(£38.12.6)	44
Used aluminium unsorted	(£96.7.6)	110

France (francs per kilo):

Electrolytic copper scrap	(£187.12.6)	250
Heavy copper	(£187.12.6)	250
No. 1 copper wire ..	(£172.12.6)	230
Light brass	(£122.0.0)	160
Zinc castings	(£51.0.0)	68
Lead	(£69.0.0)	92
Aluminium	(£129.12.6)	173

Italy (lire per kilo):

Aluminium soft sheet clippings (new) ..	(£200.15.0)	340
Aluminium copper alloy	(£132.17.6)	225
Lead, soft, first quality	(£75.12.6)	128
Lead, battery plates	(£41.17.6)	71
Copper, first grade	(£215.10.0)	365
Copper, second grade	(£203.2.6)	345
Bronze, first quality machinery	(£197.5.0)	335
Bronze, commercial gunmetal	(£170.2.6)	285
Brass, heavy........	(£138.15.0)	235
Brass, light	(£126.17.6)	215
Brass, bar turnings ..	(£132.17.6)	225
New zinc sheet clippings	(£65.0.0)	110
Old zinc	(£50.2.6)	85

Light Metal Statistics

Figures showing the U.K. production, etc., of light metals for April, 1959, have been issued by the Ministry of Supply as follows (in long tons):—

Virgin Aluminium	
Production	1,928
Imports	19,499
Despatches to consumers	25,653
Secondary Aluminium	
Production	9,870
Virgin content of above......	1,049
Despatches (including virgin content)	9,727
Scrap	
Arisings	13,214
Estimated quantity of metal recoverable	9,269
Consumption by:	
(a) Secondary smelters......	11,973
(b) Other uses	1,159
Despatches of wrought and cast products	
Sheet, strip and circles	13,071
Extrusions (excluding forging bar, wire-drawing rod and tube shell):	
(a) Bars and sections........	2,953
(b) Tubes (i) extruded	158
(ii) cold drawn ..	647
(c) (i) Wire	2,256
(ii) Hot rolled rod (not included in (c) (i)	24
Forgings	341
Castings: (a) Sand	1,636
(b) Gravity die....	4,214
(c) Pressure die ..	1,831
Foil	2,116
Paste	257
Magnesium Fabrication	
Sheet and strip	18
Extrusions	31
Castings	163
Forgings	8

LIGHT METALS STATISTICS IN JAPAN

(March, 1959)

Classification	Production	Shipment	Stock	Export
Alumina	26,857	25,567	16,524	8,130
Aluminium				
Primary	7,894	8,484	2,359	102
Secondary	2,588	2,551	371	0
Rolled Products	7,364	7,673	1,607	794
Electric Wire	740	437	846	14
Sheet Products	1,600	1,486	1,225	105
Castings	1,973	—	—	—
Die-Castings	1,245	—	—	—
Forgings	22	—	—	—
Powder	—	—	—	—
Primary Aluminium (April)	8,113	8,477	1,995	0
Sponge Titanium	206	162	683	150
Magnesium	122	115	57	0
Secondary	276	282	35	0

THE STOCK EXCHANGE

The Market For Industrials Kept Active And Strong

ISSUED CAPITAL •	AMOUNT OF SHARE	NAME OF COMPANY	MIDDLE PRICE 25 AUGUST	+RISE—FALL	DIV. FOR LAST FIN. YEAR	DIV. FOR PREV. YEAR	DIV. YIELD	1959 HIGH	1959 LOW	1958 HIGH	1958 LOW
£	£				Per cent	Per cent					
4,435,792	1	Amalgamated Metal Corporation ...	27/3	+9d.	9	9	6 12 0	27/4½	23/3	24/9	17/6
400,000	2/-	Anti-Attrition Metal	1/3		4	8¼	6 15 0	1/6	1/3	1/9	1/3
41,303,829	Stk. (£1)	Associated Electrical Industries ...	62/-	—9d.	15	15	4 17 0	63/6	54/-	58/9	46/6
1,613,280	1	Birfield	59/6	+7½d.	15	15	5 0 9	59/6	46/9	62/4½	46/3
3,196,667	1	Birmid Industries	82/-	+1/-	17½	17½	4 5 6	82/-	72/-	77/6	55/3
5,630,344	Stk. (£1)	Birmingham Small Arms	45/-	+6d.	11	10	4 17 9	48/3	36/1½	39/-	23/9
203,150	Stk. (£1)	Ditto Cum. A. Pref. 5%	15/6		5	5	6 9 0	16/3	15/-	16/1½	14/7½
350,580	Stk. (£1)	Ditto Cum. B. Pref. 6%	18/10½		6	6	6 7 0	18/10½	17/9	17/4½	16/6
500,000	1	Bolton (Thos.) & Sons	33/9	—3d.	10	10	5 18 6	34/-	27/6	28/9	24/-
300,000	1	Ditto Pref. 5%	15/6	+3d.	5	5	6 9 0	15/6	14/-	16/-	15/-
160,000	1	Booth (James) & Co. Cum. Pref. 7%	20/6		7	7	6 16 6	20/6	20/-	20/4½	19/-
1,500,000	Stk. (£1)	British Aluminium Co. Pref. 6% ...	20/6		6	6	5 17 6	20/7½	18/9	20/-	18/4½
17,247,070	Stk. (£1)	British Insulated Callender's Cables	53/3	+1/3	12½	12½	4 14 0	57/-	46/3	52/6	38/9
17,047,166	Stk. (£1)	British Oxygen Co. Ltd., Ord. ...	65/-	+1/3	10	10	3 1 6	65/-	49/3	52/-	28/3
1,200,000	Stk. (5/-)	Canning (W.) & Co.	15/6	+9d.	25+*2¼C‡	25	4 0 9	16/-	12/3	25/3	19/3
60,484	1/-	Carr (Chas.)	2/7½		12½	25	4 15 6	2/7½	1/3	2/3	1/4½
555,000	1	Clifford (Chas.) Ltd.	25/-		10	10	8 0 0	24/9	22/6	22/-	16/-
45,000	1	Ditto Cum. Pref. 6%	16/9		6	6	7 3 3	16/9	15/3	16/-	15/-
250,000	2/-	Coley Metals	3/-		15	20	10 0 0	4/-	2/10½	4/6	2/6
10,185,696	1	Cons. Zinc Corp.†	67/6	+9d.	15	18¾	4 9 0	69/3	59/-	65/3	41/-
1,509,528	1	Davy & United	72/6	+1/6	30‡	20	4 2 9	72/6	43/1½	87/-	45/9
6,840,000	5/-	Delta Metal	18/-	+1/-	31‡	30	4 6 0	18/-	12/-	25/-	17/7½
5,296,550	Stk. (£1)	Enfield Rolling Mills Ltd.	56/9	+3/-	15	12½	5 5 9	57/6	36/7½	38/-	22/9
750,000	1	Evered & Co.	35/9		10 §	15 Z	5 12 0	35/9	30/-	30/-	26/
18,000,000	Stk. (£1)	General Electric Co.	38/-	+6d.	10	10P	5 5 3	40/3	30/-	40/6	29/6
1,500,000	Stk. (10/-)	General Refractories Ltd.	37/6	+3/6	20	20	5 6 9	40/-	32/6	39/3	27/3
401,240	1	Gibbons (Dudley) Ltd.	63/-	—1/-	16½	15	5 4 9	66/6	63/6	67/6	61/-
750,000	5/-	Glacier Metal Co. Ltd.	8/3		11¼	11¼	6 18 9	9/3	6/7½	8/3	5/-
1,750,000	5/-	Glynwed Tubes	21/6		20	20	4 13 0	22/9	16/4½	18/1½	12/10½
5,421,049	10/-	Goodlass Wall & Lead Industries ...	38/9	+3d.	13‖	18Z	3 4 6	38/9	28/7½	30/9	17/3
342,195	1	Greenwood & Batley	105/-		30	20	5 14 3	108/3	75/-	57/9	45/-
396,000	5/-	Harrison (B'ham) Ord.	19/9	—3d.	*17½	*15	4 8 6	20/-	14/11½	15/9	11/6
150,000	1	Ditto Cum. Pref. 7%	19/3		7	7	7 5 6	—	—	19/9	18/4½
1,075,167	5/-	Heenan Group	10/6		10	10‡	4 15 6	10/6	7/6	9/7½	6/9
236,958,260	Stk. (£1)	Imperial Chemical Industries ...	40/-		12Z	10	4 0 0	40/3	33/9	38/-	24/3
34,736,773	Stk. (£1)	Ditto Cum. Pref. 5%	17/9		5	5	5 12 9	17/9	16/-	17/1½	16/-
14,584,025	**	International Nickel	183	—2	$2.60	$3.75	2 12 0	187¾	154½	169	132¾
300,000	1	Johnson, Matthey & Co. Cum. Pref. 5%	16/3	+6d.	5	5	6 3 0	16/3	15/4½	16/9	15/-
6,000,000	1	Ditto Ord	41/6	+4/-	12D	10	3 17 0	42/-	29/7½	47/-	36/6
600,000	10/-	Keith, Blackman	30/-		17½E	15	5 16 9	30/3	25/-	28/9	15/-
320,000	4/-	London Aluminium	5/9		10	10	6 17 6	6/9	5/3	6/-	3/-
765,012	1	McKechnie Brothers Ord.	41/-	—3d.	15	15	7 6 3	45/-	41/-	45/-	32/-
1,530,024	1	Ditto A Ord.	38/9		15	15	7 14 6	43/6	38/9	45/-	30/-
1,108,268	5/-	Manganese Bronze & Brass	14/3		20⅝	20	7 6 3	16/3	13/9	14/1½	8/9
50,628	6/-	Ditto (7½% N.C. Pref.)	6/-		7½	7½	7 10 0	—	—	6/3	5/6
13,098,855	Stk. (£1)	Metal Box	58/6	+2/3	11	11	3 15 3	60/4½	44/7½	73/3	40/6
415,760	Stk. (2/-)	Metal Traders	11/9	+1/3	50	50	8 10 3	11/9	8/4½	9/-	6/3
160,000	1	Mint (The) Birmingham	27/6	+1/-	10	10	7 5 6	27/6	22/-	22/9	19/-
80,000	5	Ditto Pref. 6%	70/-		6	6	8 11 6	75/6	69/-	83/6	69/-
3,705,670	Stk. (£1)	Morgan Crucible A	55/3	+9d.	10	10	3 12 6	54/6	43/6	45/-	34/-
1,000,000	Stk. (£1)	Ditto 5½% Cum. 1st Pref. ...	18/3		5½	5½	6 0 6	18/6	17/6	18/-	17/-
2,200,000	Stk. (£1)	Murex	46/3xd	—3/-	15	17½	6 9 9	51/-	41/-	58/9	46/-
468,000	5/-	Ratcliffs (Great Bridge)	11/6		10R	10	3 5 3	11/6	9/6	11/1½	6/10½
234,960	10/-	Sanderson Bros. & Newbould ...	40/-		25	20	6 5 0	40/-	27/9	27/3	24/6
1,365,000	Stk. (5/-)	Serck	23/-	+2/-	15	17½	3 5 3	23/-	18/-	18/7½	11/-
6,698,586	Stk. (£1)	Stone-Platt Industries	51/6	+1/-	15	15	5 12 3	53/6	42/6	45/6	22/6
2,928,963	Stk. (£1)	Ditto 5½% Cum. Pref.	17/6	—6d.	5½	5½	6 5 9	18/-	15/10½	16/3	12/7½
18,255,218	Stk. (£1)	Tube Investments Ord	90/-	+1/-	17½	15	3 17 9	91/6	72/-	86/-	48/4½
41,000,000	Stk. (£1)	Vickers	32/-		10	10	6 5 6	37/-	29/9	36/3	28/9
750,000	Stk. (£1)	Ditto Pref. 5%	15/-		5	5	6 13 9	15/0¾	14/3	15/9	14/3
6,863,807	Stk. (£1)	Ditto Pref. 5% tax free	22/-		*5	*5	6 15 3A	22/7½	20/6	23/-	21/3
2,200,000	1	Ward (Thos. W.), Ord.	98/6	+3/-	20	15	4 1 3	98/6	83/-	87/3	70/9
2,666,034	Stk. (£1)	Westinghouse Brake	44/6	+1/6	10	10	4 10 0	47/-	39/9	46/6	32/6
225,000	2/-	Wolverhampton Die-Casting ...	10/1½		30	25	5 18 6	10/6	8/8¼	10/1½	7/-
591,000	5/-	Wolverhampton Metal	31/-	+3/3	27½	27½	4 8 9	31/6	21/6	22/9	14/9
78,465	2/6	Wright, Bindley & Gell	7/-		20	20	7 2 9	7/-	4/11½	5/4½	2/9
124,140	1	Ditto Cum. Pref. 6%	13/9		6	6	8 14 9	13/9	13/6	13/-	11/3
150,000	1/-	Zinc Alloy Rust Proof	3/9	+3d.	27	40D	7 4 0	3/9	2/9	3/1½	2/7½

*Dividend paid free of Income Tax. †Incorporating Zinc Corpn. & Imperial Smelting. **Shares of no Par Value. ‡ and 100% Capitalized issue. • The figures given relate to the issue quoted in the third column. A Calculated on £7 8 9 gross. Y Calculated on 11¼% dividend. ‖Adjusted to allow for capitalization issue. E for 15 months. D and 50% capitalized issue. Z and 50% capitalized issue. B equivalent to 12½% on existing Ordinary Capital after 100% capitalized issue. ϕ And 100% capitalized issue. X Calculated on 17½%. C Paid out of Capital Profits. E and 50% capitalized issue in 7% 2nd Pref. Shares. P Interim dividend since reduced. § And Special distribution of 2½% free of tax. R And 33⅓% capitalized issue in 8% Maximum Ordinary 5/- Stock Units.

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